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9. ABSTRACT

This book discusses principles and methods of planning technical education programs. It includes a brief discussion of the polytechnical educational system in Bangladesh as of 1970. The chapters discuss efficiency in resource allocation, student flows and stocks of graduates, costs and financing of technical education, employment and earnings of graduates, a decision model for planning technical education, and implementation of the decision model. The appendix on Bangladesh polytechnics is based on data no more recent than 1970. Some of the points made: The first polytechnic diploma program was founded in Dacca in 1955. After 1962, several technical institutes were upgraded to diploma-issuing polytechnics, and new polytechnics were established. By 1970 they were graduating a total of about 1,000 diploma-level civil, electrical, mechanical, or power engineers (DLE/s). The gap between the training objectives and employment opportunities, present from the beginning, is widening. The foreign-influenced, research-oriented curricula bear little relevance to industrial needs. Initial unemployment of DLE's is high; most enter government positions. The 18 existing (c. 1970) polytechnics are centrally organized, funded, and directed by the government Directorate of Technical Education. As of 1970, the total number of DLE's was 5,000, compared to 2,700 degree engineers and 12,500 certificate holders.

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Methodology for Planning Technical Education

PREFACE AND ACKNOWLEDGMENTS

This book is the product of research first begun by one of the authors (Jozef M. Ritzen) in Bangladesh—then still East Pakistan— in 1969 and 1970. Those research activities were sponsored by the Ford Foundation under the Pakistan-Berkeley Program.

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This book
is dedicated to

Charles S. Benson
for his friendship and constant encouragement
in our professional efforts

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Methodology for Planning Technical Education

CHAPTER

1

EFFICIENCY IN RESOURCE ALLOCATION

PLANNING AND EDUCATION

Rapid social and technical change of the twentieth century has placed added burdens on many institutions of society. These institutions have increased in sheer size and have expanded considerably in diversity, while, at the same time, their goals have been constantly shifting. Relating the functioning of these systems to public needs has thus become increasingly difficult.

Educational institutions are a case in point. A gap is felt between what schools do and what they ought to do. Educators everywhere feel the pressures to improve their organizations in the context of a complex society through better planning, monitoring, and control. Meanwhile, all over the world, the public demands that schools become more responsive to desired social and economic goals, and alternatives to existing institutions are proposed such as, for example, nonformal education.[1]

Moreover, along with the increasing complexity of educational systems, there tends to be more time required between central decisions and implementation and greater time lags in the feedback of information to those who determine policy. Thus decisions must be made more comprehensively and over a longer time interval than before.

Major efforts to cope with these relatively recent problems have created the need for a number of quantitative planning techniques on the one hand and control and monitoring techniques on the other. The best of these techniques make it possible to relate social needs to institutional response. PPBS—planning,

programming, budgeting systems—is one result of these efforts. With PPBS, a budget is drawn up by program rather than by cost category and cost benefit analysis is used to decide on the most cost effective ways to reach the program goals.[2] PPBS, then, is essentially a technique to help the educational administrator in the monitoring and control of educational systems, rather than for long-term planning. Other methods such as MIS (management information systems) have emerged concurrently with PPBS. These systems have been developed because it is recognized that a well-developed information feedback from the school sites to administrators, planners, and policy makers, and vice-versa, is essential for both short-term and long-term planning and control.[3]

The development and international dissemination of techniques for medium- and long-term planning has been greatly stimulated by the International Institute of Educational Planning of UNESCO and the Centre for Educational Research and Innovation of the Organization for Economic Cooperation and Development (OECD).[4] Mathematical modeling of the student flow is the most widely used of these methods. In such models the student flow is characterized by the promotion, repetition, and dropout rates over a certain period (one or more years).

In every part of the educational system different types of problems are encountered. Generalized frameworks, like MIS or educational flow models, have to be tailored to the specific situations of these subsystems. The specific subsystem to be explored in this book is technical education; here we shall develop a comprehensive set of methods for planning technical education. Wherever possible we shall draw on existing tools, fitting them to the specific context of technical education. But in many instances we are faced with planning problems for which existing methods are ill suited. In such cases we have developed new planning tools. These tools are equally applicable in developed and developing countries. In this study they are exemplified for polytechnics in Bangladesh.

TECHNICAL EDUCATION AND INDUSTRIALIZATION

The twentieth century is characterized by accelerated industrial growth in all countries. Industrialization is the key to growth of the gross national product. Governments encourage and stimulate industrial development. Large proportions of their investment budgets are allocated for industries, and taxation and subsidies are geared to promote private investments in the industrial sector.

The resulting rapid pace of investments in factories and mills has created an immediate shortage of technical manpower, a problem compounded by the shortage (and sometimes complete absence) of training facilities for technical

manpower. This problem has been particularly acute for the developing countries. While developed countries have been able to build up their training facilities over a century, in gradual response to developing industrial needs, developing countries have been forced to do so in one or two decades.

In the relatively poor developing countries, crash programs for technical education have been established by international organizations and foreign assistance programs. The World Bank, the Ford Foundation, UNESCO, the U.S. Agency for International Development, to mention a few large organizations, have been involved in providing technical expertise for the establishment of technical schools, polytechnics, engineering colleges, etc.

Little attention has been given to the continuing planning, control, and monitoring of technical schools once they are set up. Foreign assistance programs are heavily biased toward the provision of capital outlay and foreign consultants but leave much of the ensuing administration to the receiving country's government. These governments generally suffer from a shortage of qualified analysts and planners; often they are totally unprepared to cope with the large size and complexity of the newly emerged structure of technical education.

As a result many developing countries have experienced runaway costs, low internal efficiency, large-scale unemployment, and underemployment of graduates in their technical education programs. Responsibility for these problems rests on a number of factors: (1) reliance on institutionalized training, ignoring on the job and apprenticeship training as viable alternatives; (2) modeling technical training programs according to the examples of programs existing in the United States or Europe, oriented as much to research as to practical use in factories; and also (3) the lack of evaluation and planning of technical education.

Problems 1 and 3 are also encountered in the developed countries. At the same time the developing countries are least able to afford wastage; while efficiency in resource allocation is important in all countries, in developing countries it is of crucial significance in combating malnutrition and starvation and in building a stronger economy.

Bangladesh is a case in point. Per capita income is among the lowest in the world and malnutrition is widespread. Wastage in resource allocation must be avoided. And yet the contrary seems to happen in technical education. Capacity continues to increase, despite large-scale unemployment of technical manpower and despite the huge costs involved.

There are other, more pragmatic reasons why we have selected polytechnics in Bangladesh for our case study. The large degree of centralization of technical education and the relatively small number of institutions involved made data collection and analysis easier. Because of an opportunity to work in the Planning Department of East Pakistan (later Bangladesh) with the help of the

Ford Foundation, we were able to gain understanding of their system from a close vantage point.

RATIONALE AND OUTLINE OF THIS BOOK

Technical and professional education programs are, more than any other branches of the educational system, aimed directly at supplying manpower to perform certain jobs and to fill certain occupations. The goals and objectives of technical and professional training are therefore relatively more concrete and more easily quantified than those of other segments of the educational system. Thus once manpower requirements are known, it is possible to define in rough terms the planning process for technical and professional education to meet these needs.

Between the allocation of resources (investments in education) and the satisfaction of manpower requirements, three stages are to be distinguished:

1. *Financing of Education.* Resources are used for the maintenance of existing capacity or the creation of new places for students. The costs per student place will determine the ultimate number of students that can be accommodated with these resources. This stage is described by the finance and cost structure of the system.

2. *Student Flow.* Students who occupy these places need not complete their education within the normative time set. Some may never complete, but may drop out, whether compelled to do so or by their own choice. Others may repeat, spending a second year in a class. The student flow characteristics of dropout, repetition, and promotion give a description of the second stage between educational investments and the satisfaction of manpower needs. Combined with the cost structure the planner can learn from these flow characteristics how many student place years it takes to produce one graduate.

3. *Employment.* Graduation may be the end of the horizon as far as the school principal is concerned, but the educational planner must look all the way to the labor market. Are graduates finding employment, and at what salaries? Are they working above or below the levels they have been trained for? Was the training adequate in the theoretic and practical content of the training program? etc. These are questions to be encountered at this stage.

These three stages require different lines of inquiry and different tools for analysis. For an integrated planning effort the analysis must be woven into a more comprehensive decision model. This is the main focus of this book and is found in Chapter 5. Chapters 2 to 4 deal with each of these stages separately, while the Appendix provides the background of the "case" used to exemplify these methods: polytechnics in Bangladesh. In Chapters 2 to 5, as a rule we first

deal with "theory" and then "application" to the specific case study. But it should be borne in mind that the theory was developed with the application in mind.

The analysis and mathematical modeling of the student flow is discussed in Chapter 2. The student flow can be seen as the pipeline from which trained manpower emerges after some time. Mathematical modeling of the student flow is a method by which a policy maker can find out how many new students should be admitted to the first-year class in order to produce, at a later time, a desired number of graduates; alternatively, it provides a method for determining how many graduates can be expected if a given number of students is admitted to the first-year class. In order to build a mathematical model, the characteristics of the student flow have to be identified. Measures of the flow of students through a school are flow rates, like repetition, promotion, dropout, input-output, and pass rates. The meaning of each of these measures is discussed in Chapter 2.

Flow characteristics can be useful for evaluating the internal efficiency of the school. A large number of dropouts confined with a high degree of repetition presents a picture of internal wastage. One can distinguish between internal and external efficiency so that internal efficiency is only concerned with student flow and external efficiency with the employability of graduates. These measures have been applied to the case of polytechnics in Bangladesh with the twofold goal of evaluating internal efficiency and developing a mathematical model of the student flow. The mathematical model is used to project the stock of graduates for up to the year 1978.

The analysis of the costs of an educational institution is the subject of Chapter 3. The costs to society at large (social costs) and to the individual (private costs) are distinguished. For purposes of planning one ought to consider separately capital costs (the expenditures for items that last for a long period) from annually recurring costs (the bulk of which are teachers' and staff salaries).

The educational planner is frequently confronted with one common cost account for a number of educational programs. But student cost per program is important information for the educational planner, which, however, cannot be obtained from the common account. In Chapter 3 we demonstrate a statistical technique to decompose the total costs over costs by program. The technique will yield meaningful results if the per student costs for each program are similar across the educational institutions where the programs are offered. This decomposition method of educational costs is exemplified for polytechnics in Bangladesh.

In Chapter 4, methods for analyzing the employment of graduates are presented. A basic point of departure is, as with the student flow, the development of a set of measures that describes the characteristics of the employment

market for graduates. A most important measure is the period of unemployment after graduation, since graduates in India and Bangladesh seem to suffer unemployment, if at all, immediately after graduation.[5] We show how to reconstruct an unemployment rate, from ex post data on the period of unemployment. The employment prospects of an individual graduate presumably depend on a number of variables. Some of these are personal characteristics, others are general employment market characteristics. The relation between such variables is discussed and statistically analyzed for graduates from polytechnics.

Chapter 5 is an effort to bring together the techniques of the preceding chapters in a decision model. An important component of this model is a management information system. The data produced by this structure should enable administrators at either central coordination or the school site (principals) to arrive at better decisions concerning expansion or contraction of enrollment capacity, improvement of internal efficiency, relevancy of the training for jobs, as well as the cost effectiveness of the training. For the planner, the management information system is also a prerequisite for updating any planning models or techniques used. Since education, like most social systems, does not conform according to a set of more or less well-known "physical" laws, the relations between variables remain of a statistical nature. they change to a large extent unpredictably. For planning purposes we need to inquire, at regular intervals, what the new relationships are as they develop.

A second component is a policy explication framework. The more a policy can be stated in quantitative terms, the more responsive the resource allocation can be made to the policy. Since we focus on technical education the policy explication framework is mainly concerned with manpower targets, which leads to the third component, manpower forecasts.

Forecasting employment has been and still is one of the most elusive tasks with which economists and other social scientists are engaged.[6] Manpower projections have often proven to be quite inaccurate. But even manpower projections do have an advantage over forecasts by "rule of thumb"; they enable the forecaster to include more and better information as it becomes available.

A last component of the decision model is a method for deriving optimal investment decisions for technical education. This method relies heavily on the framework of student flow and demand projection developed for the other components. The solution of this optimization problem is achieved with the technique of quadratic programming.

Chapter 6 discusses the scope and limitations of the tools developed. The usefulness of these planning techniques for policy purposes is explored in cost benefit terms and suggestions are made for further research.

The intention of this study has been to contribute to the methodology of planning educational systems, while touching on some of the most pressing problems encountered in the real world. We are quite aware, however, that

much more needs to be done. Analysis of what happens inside the school (teaching methods, curriculum, etc.) and examination of the relation between job content and training are among those subjects that are essential for proper planning and require further study. We hope that this book will stimulate others to contribute to knowledge and understanding in this field.

NOTES

1. Philip H. Coombs, *The World Educational Crisis—A Systems Analysis* (New York: Oxford University Press, 1968).

2. For further elaboration of PPBS in education, see Harry J. Hartley, *Educational Planning, Programming, Budgeting—A Systems Approach* (Englewood Cliffs, N.J.: Prentice-Hall, 1968).

3. The Organization for Economic Cooperation and Development (OECD) has produced a study of the data needs for short-, middle-, and long-term planning of educational systems: *Methods and Statistical Needs of Educational Planning* (Paris: OECD, 1967). See also Sherman C. Blumenthal, *Management Information System: A Framework for Planning and Development* (Englewood Cliffs, N.J.: Prentice-Hall, 1969).

4. See J.D. Chesswas, *Methodologies of Educational Planning for Developing Countries* (Paris: UNESCO/IIEP, 1969) and OECD, *Mathematical Models in Educational Planning* (Paris: OECD, 1967).

5. The evidence of M. Blaug et al. and M. Obaidullah to this effect is confirmed by our study: M. Blaug, P.R.G. Layard, and M. Woodhall, *The Causes of Graduate Unemployment in India* (London: Allan Lane, The Penguin Press 1969); M. Obaidullah, "A Study of Employment Survey of Graduates," Institute of Statistical Research and Training, University of Dacca, 1971 (mimeographed report).

6. For a detailed survey of manpower forecasting literature, see B. Ahamed and M. Blaug, *The Practice of Manpower Forecasting* (San Francisco: Jossey Bass, 1973).

CHAPTER

2

STUDENT FLOWS AND STOCKS OF GRADUATES

PLANNING ENROLLMENT CAPACITY

Rational educational planning decisions, inasmuch as they are framed in economic terms, rely heavily on information on demands and supplies. Demands can be related to social demands or manpower needs, and in Chapter 4 of this study we concentrate on the latter. Social demand arises from individuals who want to be enrolled, while the manpower requirements approach starts at the other end of the education system, considering the number of graduates needed in the economy. Supplies, or numbers of graduates, are more easily measured components of the system. In this chapter we examine supplies of graduates trained in various technical fields in order to compare supplies with demands for them, measured in terms of employment opportunities.

Moreover, if planning is to be done effectively—that is, resources are allocated so as to plan capacity of various kinds of schools optimally—within the system itself, there must be a continuing analysis of how well the job is done. A number of methods are being used to examine educational efficiency (for example, comparisons of numbers of entrants with numbers of graduates or the length of time spent in the educational process) and these techniques and measures are necessary in the initial planning of institutions as well as in monitoring their efficiency once they are underway.

For planning, projections of training capacity are required. Forecasts should include the supply of qualified teachers to do the training as well as forecasts of the physical plant capacity. Since teacher training requires a lead time of several

years, the demands for teachers several years in the future is closely related to the ability to predict the future flow of students.

Looking ahead to the decision model in Chapter 5, we see that for the purposes of projection, simulation, and optimization, information on stocks of graduates and flows of students is of great importance. We shall now proceed to examine ways of looking at student flows and stocks of graduates.

MEASURING STUDENT FLOWS AND OUTPUTS

A variety of methods for measuring student flows has been proposed and some are routinely used by organizations such as university planning offices and government agencies that require analytical tools for decision making.[1] These methods include defining measures such as student attendance, promotion, graduation, and length of the interval of study that permit comparisons among institutions and departments and the objective examination of their relative efficiencies. We have selected some that are appropriate for the data most generally available.

Measurements of Student Attendance

Student attendance in a particular institution or program is of interest in terms of the way students move into, through, and out of a program from year to year. For the purpose of analysis it is important to know the size of a class throughout the year; also, one must be able to compare the number of students ready to move on to the next class at the end of a year with those who must repeat the year's work and those who drop out of the program. From such data, rates of promotion, repetition, and attrition can be computed and used for future projections. Typical problems that can be solved by using such rates are: (1) How many students should be accepted at the beginning of a program in order to produce a specified number of graduates at the end? (2) What are the relative efficiencies of programs in various departments in terms of numbers of successful graduates compared to numbers who enter?

We define the rates that we will use as follows:

Promotion rate: The proportion of students enrolled who pass the annual examination;

Graduation rate: The proportion of the number of students in the last class (measured by enrollment) who receive the diploma; the graduation rate is the promotion rate for the last-year class;

Input-output rate: The number of students who receive the diploma as a proportion of the number of students enrolled in the first-year class at the time it entered;

Repetition rate: The proportion of students enrolled who repeat in the same-year class;

Dropout rate: The proportion of students enrolled at the beginning of a year who drop out throughout the year.

In the later sections of this chapter devoted to the Bangladesh case study, we will show how certain rates are easier to measure than others because of the greater accessibility to certain kinds of data. For any practical uses, choice of one measure instead of another will depend upon the form in which data ordinarily are collected.

Measuring Outputs of Educational Institutions and Stocks of Trained Manpower

In order to be able to compare manpower needs and resources, knowledge of the supply of trained manpower is essential. This knowledge may be acquired through the use of census data, sample surveys, or records kept by the educational institutions themselves.

If the educational institutions being studied are, as in the case of the Bangladesh polytechnics, a group of similar, government-sponsored technical schools, statistics on outputs of their graduates over time are relatively easy to find. For other kinds of educational organizations or geographical groupings, or a larger aggregation of institutions, the problems of collecting information on graduates may be enormously complicated. But even with the relative homogeneity of the schools studied in Bangladesh, we found that statistics on enrollment and graduation among institutes differ vastly in availability and accuracy. Most inaccuracies are caused by the fact that the statistics are taken at different points in time. The enrollment figure for a specific class of a certain program at a given institute will differ for different points in time of an academic year if there are any dropouts or if students can transfer between institutes and programs. Output data may differ because of the existence of supplementary examinations. Candidates who do not succeed at the regular examination may be given a chance to appear at a supplementary examination some time later. Often the results of these supplementary exams are not published until after December 31 of the year in which the student—graduated at the supplementary exam—finished his course work. In some statistics, these graduates are added to the output of the next year. In others, the output of the graduates from the regular and supplementary exam of the last year class of the same year are added.

Different definitions of the enrollment statistics are used for different purposes. We use the expression "stock calculations" to signify the total supply of graduates. For stock calculations, the definition of output is based on the time when the graduates are available on the labor market. For calculations of the efficiency of the education, however, we rely on the output of institutes of the same cohort in the last-year class, including those who graduate as regular candidates and those who pass the supplementary examinations later; and this is independent of the time the graduates join the labor force.

ANALYZING STUDENT FLOWS—THE CONCEPTUAL FRAMEWORK

A convenient method of putting together quantitative information about a system is a mathematical model. The relations that are found to describe the dynamics of the system adequately can be put in a generalized form and quantified in mathematical equations. The set of equations describing the system can serve as a model of the complex interrelationships among the variables.

This approach has been found effective in getting an understanding of, and enabling a prediction to be made about, the educational system of a country or parts of it. Different aspects of an educational system, that is, flow of students, teachers, physical facilities, teacher training facilities, costs, etc., have been shown to be quantified.

The making of mathematical models of educational systems is in a very elementary stage as yet. Models represent crude and very simplified observations of the system insofar as they tend to consider only the numerically valued enrollment variables, generally in aggregated form. Little progress has been made to date in quantifying the learning experience in the educational system.[2]

The model can be used as a tool to simulate the behavior of a system. It thus enables the planners and policy makers to assess quickly the effects of policy alternatives on the system. The results obtained from the model, however, are not definitive but only reflect the quantitative effects of the policy upon a simplification of the real system.

We shall now describe a particular model of diploma courses in Bangladesh polytechnic institutes.[3] (Also see the Appendix to this book for a general description of polytechnics in Bangladesh.) Although the model was developed for the specific Bangladesh case study, it is of general applicability. In the present discussion it will serve as an example of how the past experience of student flows and stocks can serve educational planning needs. Any such application, of course, requires attention to details of data availability and realities of the particular situation. In this case we must bear in mind the following points:

- Polytechnics offer a number of different technologies (also called courses or programs) for the student seeking a diploma.
- Enrollment in a particular year class is determined by newcomers, promotees, repeaters, and dropouts.
- Mobility between courses does not exist and has therefore been excluded from the model.
- For practical reasons (no data available), we do not consider age to be an influencing factor in determining enrollment; educational flow rates are not considered to be age specific as is done in other educational flow models. For the time being, the distinction between students according to previous academic background has been disregarded.

The conceptual framework used in collecting information on the student flow is shown in Figure 2.1. To fill out this diagram quantitatively as in the Bangladesh study of polytechnics, the following numbers are required: newcomers and transfers for each year class; repeaters from the same institute in each year class; students who appear for the annual exams; students who pass the annual exams; and promotees from the same institute in the second- and third-year classes. Such information is not available as a rule from official government statistics and has to be collected from individual institutions.

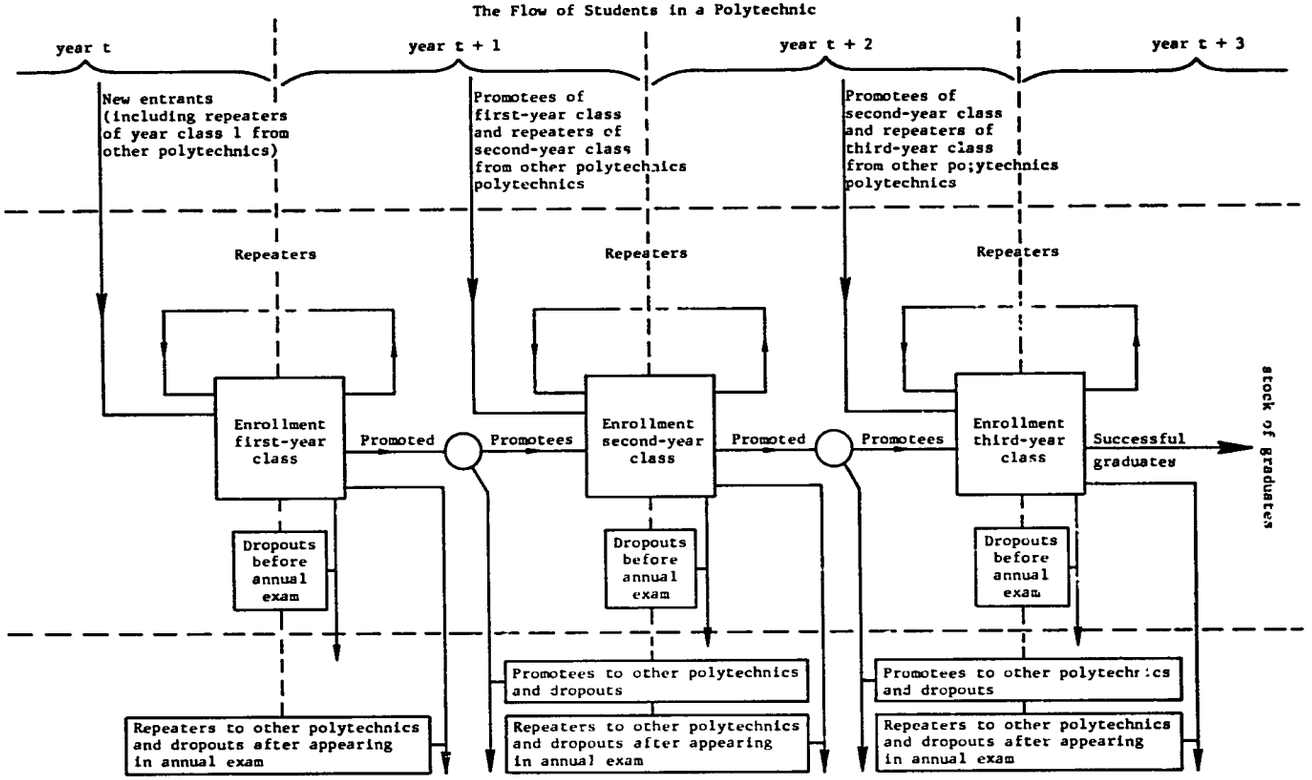
In the model, a number of coefficients appear: promotion rates, repetition rates, and dropout rates. These rates vary with time. For purposes of forecasting, it is necessary to explore the nature of these variations further.

Promotion and repetition rates are, by definition, time-dependent since the characteristics of the student flow change in the course of time. The processes and events that bring about the changes depend much on random variations. Of course, a relation does exist between the standards set for the diploma examination and these rates; a deliberate change of examination standards has a predictable impact on the rates. Similarly, these rates are not independent of the student-teacher ratio, student scholarships, student fees, and the recurring and nonrecurring expenditures per student. However, it is more difficult to quantify and forecast the impact of all of these factors on the promotion and repetition rates. Finally, fully random influences, such as the choices of individuals, are impossible to predict with current knowledge of how people make decisions. The decision to drop out after the successful completion of one year in order to take a job or shift to another field is one result of individual choices. Additionally, there is another source of uncertainty introduced by such unpredictable occurrences as strikes, wars, and natural catastrophes.

Within the simple structure of this model, we limit ourselves to the use of constant deterministic (nonrandom) student flow and attrition rates. These assumptions were tested for our Bangladesh case study by investigating the time series of graduation, pass, and attrition rates; the rates were found to be relatively constant over time.

FIGURE 2.1

The Flow of Students in a Polytechnic



The impact of the assumption of constancy and nonrandomness of flow and stock equations on the deviation of predicted stock from actual stock and enrollment sizes will depend to a large extent on: (1) the length of the time period over which predictions are made (in the Bangladesh study this period was seven years); (2) whether major policy changes in finance, teaching methods, or general course conditions have changed significantly over the planning period.

The best way to keep discrepancies between predicted and actual variables to a minimum is by updating annually the parameters of the model according to the actual values of the variables in the last year. For example, average promotion rates can be calculated over several years and adjustments made to this average as new data are collected.

In defining in mathematical terms the rates that we will need for our analysis it is arbitrarily assumed that the interval of education is three years and therefore reference is frequently made to first-, second-, and third-year classes. This was chosen because of the length of the program in our Bangladesh case study; the analysis could just as well apply to programs of any other specified duration.

DEFINITIONS OF STUDENT FLOW RATES

Promotion Rates

The promotion rate is defined by the number of promotees in a year's class $i + 1$ (where i may be 1, 2, or 3) in year $t + 1$ (where t may be any year) divided by the number of students enrolled in year class i in year t. In other words, the proportion of students in a certain year's class who participate next year in the next year's class. If the promotion rate is 1, then all students participate next year in the next year's class. If the promotion rate is 0, no students of a certain year's class participate next year in the next year's class. In mathematical formulation:

$$pp_{t,i} = (Pr_{t+1,\, i+1})/(En_{t,i}) \tag{2.1}$$

where $pp_{t,i}$ is the promotion rate of year class i in year t

$Pr_{t+i,\, i+1}$ is the number of promotees in year class $i + 1$ in year $t + 1$

$En_{t,i}$ is the number of students enrolled in year class i in year t.

The statistics of promotees of the third year class ($Pr_{t+1,4}$) is the number of graduates in year t, so we can universally apply the definition of the promotion rate to all year classes, using the term graduation rate for the third-year class.

Input-Output Rate

The combined promotion rate over all years can be expressed by the proportion of students entering in a year t who complete the course (in two or more years), in the following way:

$$pd_t = (Pr_{t,4})/(En_{t-3,1}) \tag{2.2}$$

This is called the input-output rate.

Pass Rate

The pass rate of year class i at time t is defined by the number of students enrolled in a year class $i+1$ at time $t+1$ divided by the number of students enrolled in the year class i in year t and is denoted by $ps_{t,i}$. This can be written as:

$$ps_{t,i} = (En_{t+1,i+1})/(En_{t,i}) \tag{2.3}$$

The pass rate is not a very precise measurement of efficiency. The enrollment of a year class is composed of promotees, repeaters, and newcomers from other equivalent schools. The pass rate thus always exceeds the promotion rate if there are repeaters and newcomers. There is little relation between numbers of enrollees, repeaters, and newcomers. Pass rates may exceed the unity value according to the definition. The difference between pass and promotion rates is minimal for expanding institutions, such as those in Bangladesh, because regularly progressing enrollees are the greatest number in proportion to the total. The difference is greatest in institutions that are decreasing their training capacity because there are relatively few new enrollees progressing through the system.

Repetition Rate

If $rn_{t,i}$ is the repetition rate for students in year class i in year t, then $rn_{t,i}$ is defined by:

$$rn_{t,i} = (R_{t+1,i})/(En_{t,i}) \tag{2.4}$$

and $R_{t,i}$ is the number of students repeating year class i in year t.

Dropout Rate

If the number of students who drop out in a year t from class i is denoted by $D_{t,i}$ then the dropout rate $d_{t,i}$ is defined as follows:

$$d_{t,i} = (D_{t,i})/(En_{t,i}) \tag{2.5}$$

Relations between Rates

Since students either are promoted, repeat, or drop out it follows that

$$d_{t,i} + rn_{t,i} + pp_{t,i} = 1 \tag{2.6}$$

If we know two of the three rates in the equation presented, then the third is determined as well. Therefore, in student flow models we use only two of these rates—generally the promotion and the repetition rate.

The input-output rate equals the multiplication together of the pass rates of the first two year classes and the graduation rate of the following year. This can be seen, if we write the input-output rate as follows:

$$pd_t = (En_{t+1,2})/(En_{t,1}) \times (En_{t+2,3})/(En_{t+1,2}) \times (Pr_{t+3,4})/(En_{t+2,3})$$

$$= (Pr_{t+3,4})/(En_{t,1}) \tag{2.7}$$

We recognize then that:

$$pd_t = ps_{t,1} \times ps_{t+1,2} \times pp_{t+2,3} \tag{2.8}$$

The same value of the input-output rate may be acquired by different values of the two pass and the graduation rates.

It was observed that pass rates are not precise measures for judging performance and efficiency of institutions since pass rates include new entrants and repeaters in numbers enrolled; input-output rates therefore suffer from the same deficiency as they rely on the measurement of two pass rates.

STUDENT FLOWS AND MANPOWER STOCKS—THE MATHEMATICAL MODEL

The most general mathematical description of the student flow in a three-year class education system is in matrix form:

$$\begin{bmatrix} En_{t+1,1} \\ En_{t+2,2} \\ En_{t+2,3} \end{bmatrix} = \begin{bmatrix} rn_{t,1} & 0 & 0 \\ pp_{t,1} & rn_{t,2} & 0 \\ 0 & pp_{t,2} & rn_{t,3} \end{bmatrix} \times \begin{bmatrix} En_{t,1} \\ En_{t,2} \\ En_{t,3} \end{bmatrix} + \begin{bmatrix} N_{t,1} \\ N_{t,2} \\ N_{t,3} \end{bmatrix} \tag{2.9}$$

where $N_{t,i}$ is the number of new entrants in year class i in year t (which contribute to the enrollment in year $t+1$).

The equation for the second-year class (as an example) would look like:

$$En_{t+1,2} = pp_{t,1} \times En_{t,1} + rn_{t,2} \times En_{t,2} + N_{t,2} \tag{2.10}$$

In other words, the students in year class 2 in year $t+1$ are (1) the promotees from year class 1 from the previous year t; (2) the repeaters from year class 2 in the previous year t; and (3) the newcomers from other institutions. If the model is used for individual institutions, we may take into account newcomers into the second- and third-year classes. In this case the system is open, for it is possible for new students to enter from other schools. Or the model may be aggregated for all institutions of a certain type, in which case the number of new entrants into the second- and third-year classes would be zero. In the latter instance, the system is closed, since entry is impossible from any outside institutions.

The formulation given, however, does not account for the differences in the student flow in different programs. We shall now develop a model for an educational system with three-year classes, different programs, and a first-year class common to all programs. The description fits the courses offered at polytechnics. By introducing the variable $u_{t,k}$ to denote the fraction of promotees from the common first-year class entering the program k we can bring individual courses into account in the model. The enrollment equation for a second-year class in year $t+1$ then appears thus:

$$En_{t+1,2,k} = u_{t,k} \times pp_{t,1} \times En_{t,1} + rn_{2,k} \times En_{t,2,k} + N_{t,2,k} \tag{2.11}$$

The matrix equation describing the student flow in an institution with a number of n programs then changes into the form given in Figure 2.2.

FIGURE 2.2

Student Flow Matrix for n Technologies, First-Year Class Common

$$
\begin{bmatrix} En_{t+1,1} \\ En_{t+1,2,1} \\ En_{t+1,2,2} \\ \cdot \\ \cdot \\ En_{t+1,2,n} \\ En_{t+1,3,1} \\ En_{t+1,3,2} \\ \cdot \\ \cdot \\ En_{t+1,3,n} \end{bmatrix}
=
\begin{bmatrix}
rn_{t,1} & 0 & 0 & \cdots & 0 & 0 & 0 & \cdots & 0 \\
u_{t,1}pp_{t,1} & rn_{t,2,1} & 0 & \cdots & 0 & 0 & 0 & \cdots & 0 \\
u_{t,2}pp_{t,1} & 0 & rn_{t,2,2} & \cdots & 0 & 0 & 0 & \cdots & 0 \\
\cdot & & & & & & & & \\
\cdot & & & & & & & & \\
u_{t,n}pp_{t,1} & 0 & 0 & \cdots & rn_{t,2,n} & 0 & 0 & \cdots & 0 \\
0 & pp_{t,2,1} & 0 & \cdots & 0 & rn_{t,3,1} & 0 & \cdots & 0 \\
0 & 0 & pp_{t,2,2} & \cdots & 0 & 0 & rn_{t,3,2} & \cdots & 0 \\
\cdot & & & & & & & & \\
\cdot & & & & & & & & \\
0 & 0 & 0 & \cdots & pp_{2,n} & 0 & 0 & \cdots & rn_{t,3,n}
\end{bmatrix}
\times
\begin{bmatrix} En_{t,1} \\ En_{t,2,1} \\ En_{t,2,2} \\ \cdot \\ \cdot \\ En_{t,2,n} \\ En_{t,3,1} \\ En_{t,3,2} \\ \cdot \\ \cdot \\ En_{t,3,n} \end{bmatrix}
+
\begin{bmatrix} N_{t,1} \\ N_{t,2,1} \\ N_{t,2,2} \\ \cdot \\ \cdot \\ N_{t,2,n} \\ N_{t,3,1} \\ N_{t,3,2} \\ \cdot \\ \cdot \\ N_{t,3,n} \end{bmatrix}
$$

While $u_{t,1} + u_{t,2} + \cdot \cdot \cdot + u_{t,n} = 1$

The fractions $u_{t,k}$ are decision variables. The distribution of second-year students over the different courses is determined by the available training capacity in specific programs and can change considerably over time.

The ratios presumably change because of policy decisions based on the expected demand for graduates of a particular type. The ratios can only be changed, however, by the creation of new training capacity in the second and third years, since the transfer of enrollment capacity from one program to another must be regarded as impossible; as far as teaching staff and equipment are concerned, the course structures do not possess sufficient flexibility to accommodate students from other courses. In addition, the admission capacity is a policy decision based on anticipated demand. Thus the decisions on the fractions $u_{t,k}$ and on admission capacity are not independent. Since the decision variable and the enrollment variable are multiplied, the flow equation is nonlinear. Nonlinearities are very awkward to deal with in using a model for the purpose of forecasting or control. But if we assume that specialization would start in the first-year class (and thus no common first-year class would exist), the only effective decision variable would be the admission capacity for each of the courses. Henceforth enrollment in second- and third-year classes would be determined by the flow characteristics and would not be influenced by outside decisions. Then the linear equation describing the flow of students, aggregated over all institutions, can be presented in matrix form to be for each program k:

$$\begin{bmatrix} En_{t+1,1,k} \\ En_{t+1,2,k} \\ En_{t+1,3,k} \end{bmatrix} = \begin{bmatrix} rn_{t,1,k} & 0 & 0 \\ pp_{t,1,k} & rn_{t,2,k} & 0 \\ 0 & pp_{t,2,k} & rn_{t,3,k} \end{bmatrix} \times \begin{bmatrix} En_{t,1,k} \\ En_{t,2,k} \\ En_{t,3,k} \end{bmatrix} + \begin{bmatrix} N_{t,1,k} \\ N_{t,2,k} \\ N_{t,3,k} \end{bmatrix} \tag{2.12}$$

Notice that in this form the flow equations are of exactly the same type as equation 2.9. It is apparent that for the first-year class—which is common—repetition and promotion rates across all programs are the same, or

$$pp_{t,1} = pp_{t,1,k}$$

$$rn_{t,1} = rn_{t,1,k} \tag{2.13}$$

for all k's and q's.

Later in this chapter the model will be applied to the aggregated enrollment in all polytechnics in Bangladesh. Since in that case immigration of diploma students hardly occurs, we can safely put the values of the newcomers in the second- and third-year class to zero:

$$N_{t,2,k} = N_{t,3,k} = 0 \tag{2.14}$$

for all t and k.

The output and stock have so far not been considered as part of the flow. The same reasoning and same simplifications introduced earlier are applied to the quantification of the output. The resulting equation is

$$O_{t,k} = pp_{t,3,k} \times En_{t,3,k} \tag{2.15}$$

where $O_{t,k}$ is the output of graduates of program k in year t. The variable $pp_{t,3,k}$ represents the graduation coefficient of course k.

The stock of manpower is a result of the outflow from the training institutions. The factors of retirement, death, or leaving the profession are taken together in one coefficient, the attrition rate $r_{t,k}$ which has been attached to the total stock of graduates of program k:

$$S_{t,k} = (1 - r_{t,k})S_{t-1,k} + O_{t,k} \tag{2.16}$$

where $S_{t,k}$ is the stock of manpower of program k at time t. This means that when an institution starts delivering an outflow of program k at time $t = 0$ the total stock is supposed to be:

$$S_{t,k} = O_{t,k} + (1 - r_{t,k})O_{t-1,k} + (1 - r_{t,k})^2 \times O_{t-2,k} + (1 - r_{t,k})^3 O_{t-3,k} + \cdots + (1 - r_{t,k})^t \times O_{o,k} \tag{2.17}$$

This results from expanding equation 2.16. Namely, $S_{t-1,k}$ can be written as:

$$S_{t-1,k} = O_{t-1,k} + (1 - r_{t,k})S_{t-2,k} \tag{2.18}$$

Inserting this formula into the formula of S_t gives:

$$S_{t,k} = O_{t,k} + (1 - r_{t,k})O_{t-1,k} + (1 - r_{t,k})^2 S_{t-2,k} \tag{2.19}$$

We shall now put to use the methodology described here to analyze flows and stocks of graduates of the Bangladesh polytechnic institutes.

STUDENT FLOW IN DIPLOMA COURSES AND STOCK OF GRADUATES OF BANGLADESH POLYTECHNICS

A detailed analysis has been made of the student flow in diploma courses given at polytechnics, according to the framework described. The aims of this study are (1) to describe the student flow quantitatively; (2) to analyze the efficiency of the different polytechnics in terms of student flow; and (3) to forecast the future stock formation of graduates of polytechnics on the basis of the targets for admission published by the Directorate of Technical Education (DTE).

Quantitative Description of the Student Flow

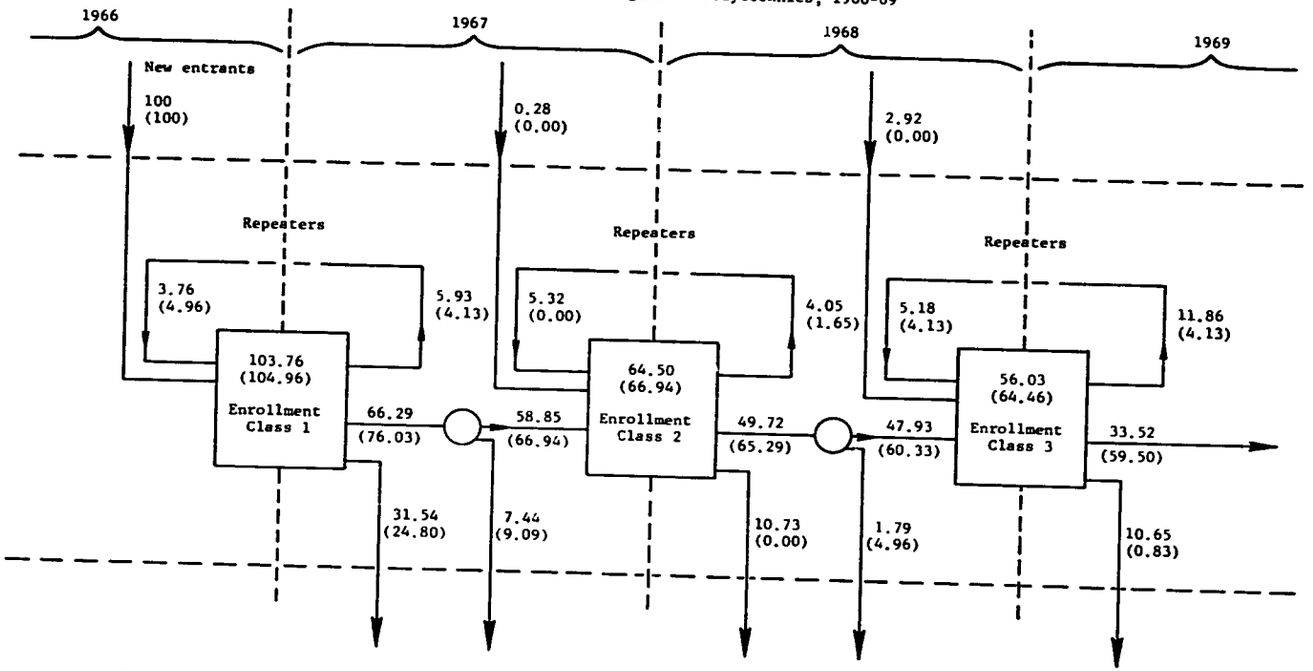
Most of the data on enrollments in diploma courses used to assess output and calculate the stock were acquired from secondary sources. The results of the stock calculations have been presented in the Appendix. Since these sources did not provide sufficient information to gain insight into the composition of enrollments, in order to distinguish between first-time enrollees, repeaters, and new arrivees from other polytechnics, detailed information was collected on enrollments from ten polytechnics individually. The data requested concerned the flow of students from 1966 up to 1970. This time series makes it possible to follow a group of new entrants in 1966 throughout their polytechnic training.

The framework for collection of these data is sketched in Figure 2.1. The number of new entrants in 1966 in the ten polytechnics surveyed was 1,062. We shall first consider these new entrants as one cohort, while aggregating technologies and institutes. For simplification, the numbers that we use in Figures 2.3 and 2.4 (following the scheme of Figure 2.1) have been normed to the base 100 of new entrants in 1966. Thus, any figure of repetition, promotion, etc., applies to every 100 newly entering students in 1966. The student flow of the 1966 cohort is recorded in Figure 2.3. In this figure the flows of dropouts and repeaters to other institutes have been combined. The first block of this figure then should read as follows:

- For every 100 new entrants (including repeaters from other polytechnics), there were 3.76 repeaters (who repeated at the same polytechnic), thus leading to an enrollment at the start of the academic year of 103.76.
- Only 66.29 of these graduated successfully from the first-year class.
- In total, 31.54 dropped out before graduation; some of these may have appeared as new entrants in other polytechnics in the year 1967.
- 5.93 repeated the first-year class in the same institution.

FIGURE 2.3

Student Flow for Ten Bangladesh Polytechnics, 1966-69



Note: This figure shows average dropout, repetition, and promotion characteristics for 100 entrants. Figure 2.1 describes this scheme in detail. Numbers in parentheses apply to students with above average entrance requirements.

Source: Compiled by the authors.

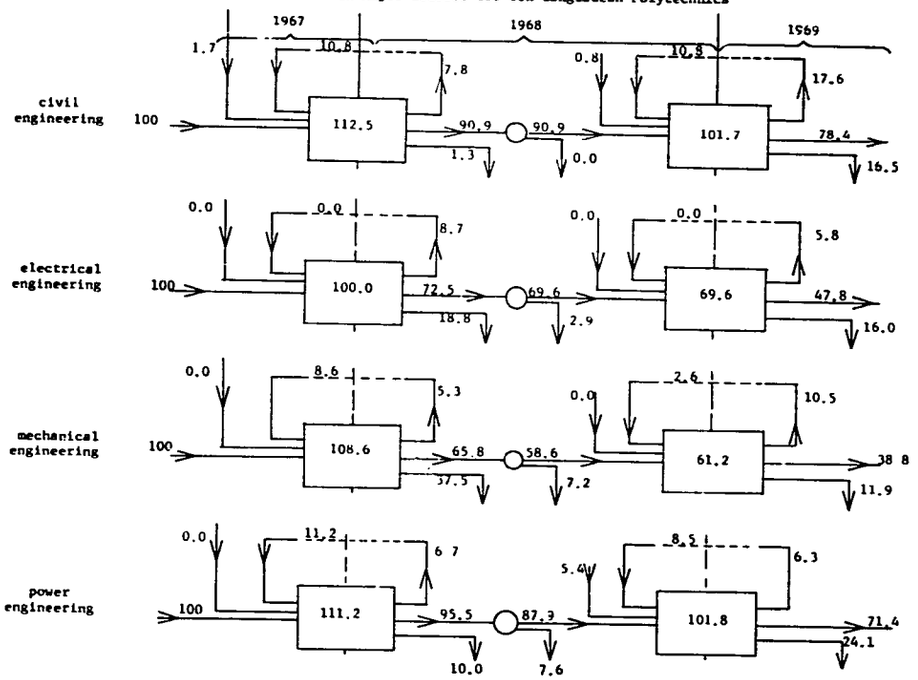
- Of the 66.29 students (per 100 new entering students in year class one in 1966), 7.44 did not enter into the second-year class in the same institute, while 58.85 continued.
- On the other hand, 0.28 students arrived in the second-year class without having been enrolled in the first-year class in the same polytechnic; this group consists of both promotees of the first-year class and repeaters of the second-year class of other polytechnics.
- From the preceding two flows, we can conclude that at least 7.16 per 100 students admitted (a "net" figure derived from outflows of 7.44 and inflows of 0.28) left the group of polytechnics after successfully passing the first-year class and dropped out.

The two other blocks can be read in the same way. We observe that the throughput in diploma courses is low. For every 100 new entrants in 1966, only 33.52 students managed to receive the diploma three years later. The low throughput rate is largely caused by the lack of "holding power" of polytechnics—mostly attributed to dropout rather than repetition. This observation documents the contention that polytechnics serve a good number of students as a cheap and comfortable base for seeking employment. Once employment is received, the diploma student simply leaves the polytechnic, whatever stage of training he is in.

Among the 1,062 entrants, 121 students held a higher secondary certificate (12 years of education) with a science background or a secondary school certificate (10 years of education) with a science background and with high grades (1st or 2nd division) when they entered the polytechnics. Thus these students had a superior academic background. The flow of these students has been indicated in parentheses in Figure 2.3. The results for these students are much better: the dropout in the second and third year is negligible and the throughput rate almost doubles that for the total body of students. In Figure 2.4 the student flow in the second- and third-year classes of the major technologies is given for the institutions surveyed starting with a base of 100 promotees to the second class in 1967-68. It appears that chances for success are better in the civil and power engineering technology than in the electrical and mechanical engineering technology. The flow of students with a science background is similar in the four major courses. The proportion of science background students is practically the same in the different technologies. These student flow characteristics are much the same among the polytechnics, with the exception of the Swedish Pakistan Institute of Technology, which has few dropouts and repeaters.

FIGURE 2.4

Flows of Students in Major Courses for Ten Bangladesh Polytechnics



Note: This figure shows average dropout, repitition, and promotion characteristics for ten polytechnics by course. See Figure 2.1.

Source: Compiled by the authors.

Admission Requirements and Achievement at the Diploma Examination

The preceding analysis looks at the student flow solely in terms of numbers without quality distinctions. Now we shall take as a measure of quality the student's grade point average at the final examination in order to compare the achievement with prepolytechnic background. The information required was collected in the employment survey described in Chapter 4, which includes academic as well as employment records.

The new entrants of polytechnic institutes can be split up into two groups: one with Higher Secondary Certificates (HSC) and another with Secondary School Certificates (SSC). The entrance requirements, published in information folders of the polytechnic institutes, list preferences for HSC candidates of the science type. Admission priority is given next to students with HSC arts qualification with marks in math above 40 percent, then to SSC science candidates, and last to SSC arts candidates with marks in mathematics above 40 percent.

In practice, 54 percent of the students comply with the minimum requirements, 29 percent of the students have an HSC, and 13 percent have an SSC science background. In Table 2.1 a comparison is made between HSC and different types of SSC graduates according to their diploma examination results. An SSC background with more than 40 percent in math is shown from the survey to obtain good final examination results. Of course, this survey only considers successful candidates. No information is collected in this survey on dropout and repetition levels according to academic qualification.

Given these relations between final examination results and the basic academic qualifications, we should question the system of admission. The preference for HSC candidates has been proven to be based on false assumptions as far as the results are concerned. It appears that the same can be said about the choice of science students over art students within the two groups. The relevance of the division obtained for the future employment position will be shown in Chapter 4. There it will appear from the earnings function and the time lag regression analysis that the division obtained at the diploma examination has little influence on the future career of the polytechnic graduate.

Efficiency in the Student Flow

The information summarized in Figures 2.3 and 2.4 has two major disadvantages for evaluating the efficiency in the student flow: (1) the data could not be collected for all polytechnics; and (2) only one cohort of students is followed, while we would prefer to be able to make comparisons over more

TABLE 2.1

Percentage Distribution of Diploma Examination Results of Polytechnic Graduates in Sample by Academic Qualifications (actual numbers in parentheses)

	Div. 1	Div. 2	Others	All
HSC	18 (9)	70 (35)	12 (6)	100 (50)
SSC science	16 (14)	76 (19)	8 (2)	100 (25)
Arts with marks above 40 percent	17 (16)	77 (71)	6 (6)	100 (93)
All others	18 (31)	74 (128)	8 (14)	100 (173)

Source: Compiled by the authors. Henceforth in this book if no source is mentioned, it will mean that the table or figure is from the authors' own research.

TABLE 2.2

Student Flow Rates, 1966-69, All Polytechnics Combined

	1966-67	1967-68	1968-69
Graduation rates (major technologies)			
Civil	0.84	1.07[a]	0.83
Electrical	0.39	0.87	0.56
Mechanical	0.48	0.66	0.48
Power	0.44	1.05	0.74
Input-output rates (all courses)	0.38	0.56	0.36
Pass rates, first-year class (common course)	0.65	0.58	0.67
Pass rates, second-year class (major technologies)			
Civil	0.95	0.97	n.a.[b]
Electrical	0.87	0.85	n.a.[b]
Mechanical	0.79	0.88	0.91
Power	0.83	0.89	0.82

[a]Some rates exceed 1.00 due to participation of external candidates.
[b]n.a. = not available.

years. However, the only other data available are total enrollments, from which we cannot extract the repetition, promotion, or dropout rates in each year. Therefore, we use instead graduation, input-output, and pass rates. Table 2.2 gives a summary of these rates, computed over all polytechnics for the years 1966-69.

Graduation Rates

The graduation rates of the various institutions vary widely; occasionally they exceed the value of 1. This occurs if external candidates (who are not enrolled) participate in the examinations. This happened on a large scale in the diploma examinations of 1968, when a strike had kept many students away from the diploma examinations in 1967.

The graduation rates for the four major technologies have one remarkable feature: the rates for civil engineering at all polytechnics are consistently and almost universally higher than the rates of the other technologies. It was found that the graduation rates for civil engineering at Dacca Polytechnic exceed the unity value for all years considered. This can only occur if students from other polytechnics appear for the diploma examination in the Dacca Polytechnic.

Figure 2.5 depicts a sequence of graduation rates over a ten-year period. For this sequence we reach the following conclusions:

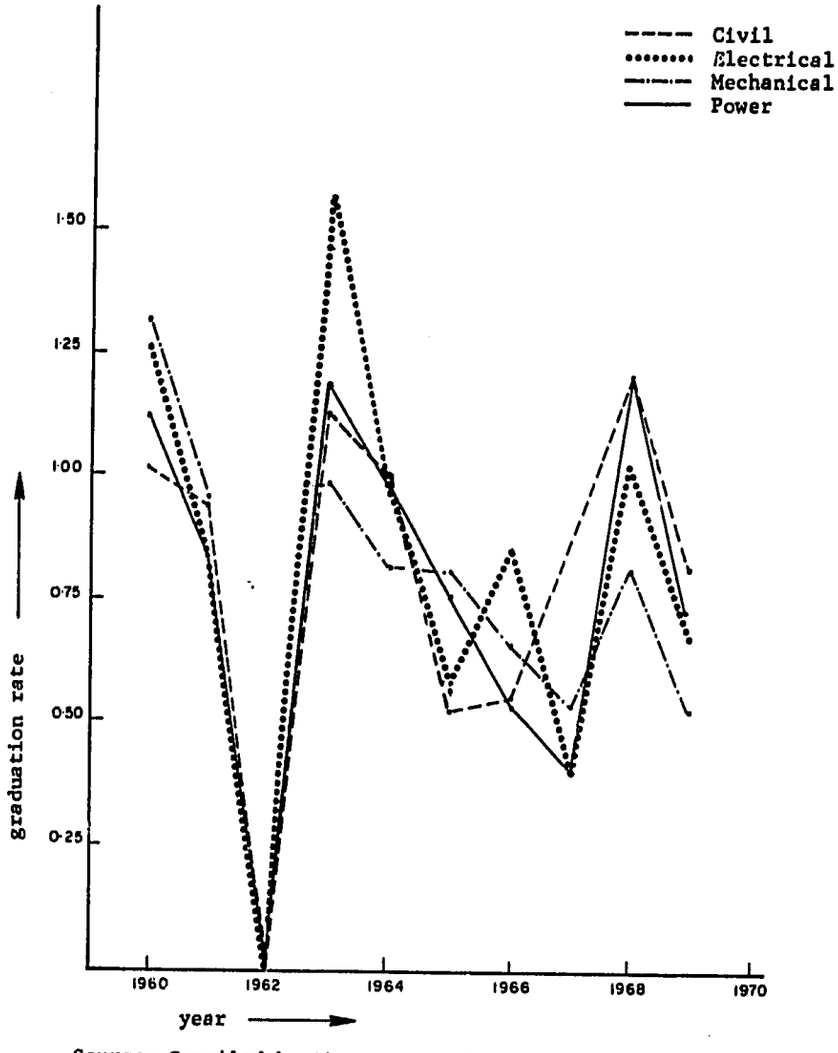
- The weighted averages of graduation rates over a period of ten years are almost equal for the civil, electrical, and power technologies (respectively, 0.77, 0.76, and 0.76). The average graduation rate of mechanical engineering is considerably less (0.60).
- The graduation rates in the past ten years have shown heavy fluctuations.
- Decreases and increases in the graduation rates tend to occur jointly for all major technologies.
- The relatively higher graduation rate of civil engineering is a recent phenomenon of the past three years.

Input-Output Rates

From computations summarized for all polytechnics in Table 2.2 it appears that the average values of the input-output rates are low (between 0.36 and 0.56). In the three years considered, some polytechnics (Jessore, Kustia, and Rajshahi) show input-output rates consistently below the average of all institutes. Their internal efficiency must be regarded as comparatively low. Others (Barisal, Pabna, and Mymensing polytechnic and the Swedish Pakistan Institute of Technology) exceed the average in their performance.

FIGURE 2.5

Trend in the Graduation Rates for all Major Technologies Combined



Source: Compiled by the authors from unpublished documents of the Directorate of Technical Education.

Pass Rates

As a substitute for the promotion rates, pass rates are used to judge the efficiency in the first- and second-year classes. Pass rates for the first-year class are more or less normally distributed over the three years considered, varying between 0.30 and 1.00. The pass rates have a fairly small range of variation compared to the graduation rates. The standard deviations for the rates are small and the distribution appears to be normal.

The aggregated pass rates of the second-year classes in the major technologies at all institutes over the past ten years (1960-69) merely show fluctuations along steady averages, namely:

Civil	0.96
Electrical	0.71
Mechanical	0.90
Power	0.85

Only the rates in electrical engineering have gone up slightly in the last three years. The capacity for the training of electrical engineers has been increasing at the same time. The increase in the pass rates thus reflects a real increase in the promotion rates.

The sequence of the first-year pass rate, the second-year pass rate of the next year, and the graduation rate of a third year might reveal something about the comparative success of selection in the first-year class. Low pass rates in the first year might indicate a more severe selection system that would sort out at an early stage which students would be able to proceed to the diploma examinations and which would not. The existence of this selection system in a particular polytechnic would be revealed by a series of low pass rates for the first-year class and a higher than average pass rate for the second-year class and graduation rate. No evidence can be found from the tables to assume that, for any polytechnic, such a relationship exists.

Student Flow and Stock Accumulation Rates

The data of Figures 2.3 and 2.4 and Table 2.2 provide a rich base for the derivation of student flow rates. Rather than going through the elaborate process of statistically estimating from actual enrollments the rates that provide the best fit, we will use a less accurate but simpler method. The rates will be estimated from the available pass rates and the student flow characteristics of nine of the ten polytechnics for which detailed information has been

collected (the Swedish polytechnic has been excluded from the sample for the obvious reason that its student flow characteristics differ substantially from those of the other polytechnics surveyed).

By combining observations from both sources, that is, the sample of nine polytechnics and the full list of all polytechnics, we can construct upper and lower limits of the averages of the rates for application over a future period. For the sample of nine polytechnics, means and standard deviations of promotion and repetition rates were computed. These are used as benchmark figures to be adjusted with the pass rates.

First-year promotion rates should be compared with the pass rates. The mean of the promotion rates of the first-year class over the nine polytechnics (0.66) exceeds the average pass rate for two of the three years recorded in Table 2.2, while, by definition, the pass rate of a year class is equal to, or greater than, the promotion rate. Thus the sample of nine polytechnics has introduced a slight upward bias in the promotion rate of the first-year class. For the projections we will make the following educated guess for the first-year class:

$pp_1 = 0.60$
with an upper level $pp_1 = 0.75$
and a lower level $pp_1 = 0.45$

First-year repetition rates will be assumed to be

$rn_1 = 0.06$
with an upper level $rn_1 = 0.11$
and a lower level $rn_1 = 0.01$

Second-year promotion rates are found to be, as expected, lower than the corresponding pass rates. The differences between the rates in different technologies seem to be exaggerated by the smallness of the sample. Promotion rates for civil and power technologies resemble the pass rates if we take the third-year repetition rate into account. We shall use the following promotion rates, based on the promotion rates of the nine institutes and the longer-term time series of pass rates:

Technology	*Estimate*	*Upper Level*	*Lower Level*
Civil	0.85	0.95	0.75
Electrical	0.75	0.85	0.65
Mechanical	0.80	0.90	0.70
Power	0.75	0.95	0.65

Second-year repetition rates will be considered to be the same for all major technologies with the values:

Mean	$rn_2 = 0.05$
Upper level	$rn_2 = 0.10$
Lower level	$rn_2 = 0.00$

The calculation of the graduation rates can rely on a ten-year time series of Figure 2.5. These rates have varied considerably over the years, but the averages have remained fairly constant. We will thus be satisfied with the rates with a small variation for the upper and lower level:

Technology	*Estimate*	*Upper Level*	*Lower Level*
Civil	0.77	0.82	0.72
Electrical	0.76	0.81	0.71
Mechanical	0.60	0.65	0.55
Power	0.76	0.81	0.71

Third-year repetition rates have been estimated from the data sources to be

	$rn_3 = 0.10$
with an upper level	$rn_3 = 0.15$
and a lower level	$rn_3 = 0.05$

Testing the Flow Model for the Past

Before using the flow model for purposes of forecasting, we will first test our quantitative description by simulating the student flow in the past, using the set of average rates derived before. The simulation only extends to the four major technologies. The stocks predicted with the model will be compared with the stocks based upon the actual outflows, as given in Table 2.3. The basic input variables of the model are the number of students newly admitted to the first-year class in each of the technologies. In reality, in most polytechnics, students do not opt for a specific technology until they have passed the first-year class. The hypothetical number of newcomers in the first-year class in each technology can be reconstructed from the total number of newcomers in that class by means of the distribution of promotees from the first-year class over the technologies of the second year. The total number of newcomers in the first-year class has been equal to the admission capacity and is, as such, a known variable. The number of promotees, however, is not known over the time period considered. Therefore, the following approximation has been used:

newcomers in the first-year class in year t in technology k
= (total admission capacity of the first-year class in year t)
X (enrollment in the second-year class in year $t + 1$ in technology k divided by the total enrollment in the first-year class year t).

or

$$Newcomers_{t,k} = Total\ Capacity_{t,1} \times (En_{t+1,2,k})/(En_{t,1}) \qquad (2.20)$$

This reconstruction does not affect in any way the enrollment in the succeeding years, since the promotion and repetition rates of the first-year class are equal for all (hypothetical) technologies. With these constructed numbers we made a calculation of the stocks of graduates of the major technologies based on assumed promotion and repetition rates. These calculations are recorded in and compared with actual figures in Tables 2.3 and 2.4. (The stocks of 1965 of Table 2.4 include output of 1965 [1964-65] and thus should be compared with the calculated stock of 1965-66. The stock of 1970 of Table 2.4 does not include output of 1970 [1969-70] and is comparable with the calculated stock of 1969-70.)

We note from this comparison that virtually all calculated stocks are lower than the corresponding actual stocks. This means that our calculations have been downwardly biased by the choice of rates. However, for the later years (1965 onward), the difference between the calculated and the actual stock decreases slightly for all technologies considered. This corresponds with the fact that the calculated total outflow of 1966-69 exceeds the actual outflows slightly in all technologies. The minimal difference between the actual and the calculated outflow 1966-69 is striking:

	Total Outflow 1966-69	
	Calculated	Actual
Civil	1,461	1,424
Electrical	330	314
Mechanical	591	587
Power	805	754

This means that—while the choices of the rates were quite appropriate for the later years (and even somewhat too high)—in the earlier years the enrollment rates must have been considerably better. That the change in enrollment rates is not random can be seen from the fact that virtually all calculated stocks in 1965 are lower than the actual ones.[4]

To illustrate the use of upper- and lower-level rates, we have also simulated the flow of students for the two patterns of combination of rates, a maximum

TABLE 2.3

Simulated and Actual Enrollments and Stocks, 1955-70 (Average Rates), Civil and Electrical Engineering

Year	Simulated Class 1	Simulated Class 2	Actual Class 2	Simulated Class 3	Actual Class 3	Simulated Stock	Actual Stock
			Civil Engineering				
1955	33	0	0	0	0	0	0
1956	47	20	27	0	0	0	0
1957	152	30	32	17	26	0	0
1958	156	94	112	27	34	13	20
1959	151	103	98	83	95	34	40
1960	168	101	112	96	97	98	140
1961	140	111	141	95	106	171	230
1962	481	95	171	104	123	242	229
1963	600	298	319	91	211	320	360
1964	769	390	390	262	436	387	569
1965	664	500	466	358	460	585	789
1966	614	448	420	461	479	855	1,032
1967	823	413	354	427	399	1,201	1,427
1968		535	429	394	358	1,518	1,887
1969				494		1,806	2,148
1970						2,168	
			Electrical Engineering				
1955	36	0	0	0	0	0	0
1956	26	22	29	0	0	0	0
1957	38	18	17	17	28	0	0
1958	26	25	27	15	17	13	23
1959	49	18	16	20	23	24	34
1960	38	31	37	16	19	39	64
1961	35	26	31	25	27	51	79
1962	84	24	43	22	27	69	70
1963	155	53	55	20	39	85	121
1964	205	98	102	42	55	99	150
1965	170	133	125	78	85	130	197
1966	284	115	108	108	123	188	267
1967	424	182	169	97	93	268	314
1968		267	222	146	145	339	407
1969				229		447	500
1970						617	

Note: Blanks appear in the table since the simulation has been carried beyond the year for which actual data was available at the time of the study.

Source: Directorate of Technical Education, unpublished documents.

TABLE 2.4

Simulated and Actual Enrollments and Stocks, 1955-70 (Average Rates), Power and Mechanical Engineering

Year	Simulated Class 1	Simulated Class 2	Actual Class 2	Simulated Class 3	Actual Class 3	Simulated Stock	Actual Stock
			Power Engineering				
1955	21	0	0	0	0	0	0
1956	40	13	17	0	0	0	0
1957	42	25	28	10	16	0	0
1958	42	28	30	20	25	8	15
1959	44	28	26	23	26	23	34
1960	39	29	32	23	20	40	64
1961	65	26	32	24	34	57	81
1962	238	42	83	22	65	75	80
1963	357	147	158	34	70	91	157
1964	473	229	234	114	137	116	216
1965	581	307	278	183	184	201	316
1966	577	379	378	249	235	338	411
1967	717	384	334	309	287	524	506
1968		469	372	319	298	764	897
1969				384		999	1,044
1970						1,282	
			Mechanical Engineering				
1955	30	0	0	0	0	0	0
1956	14	18	24	0	0	0	0
1957	16	10	9	14	24	0	0
1958	31	11	11	9	9	8	20
1959	41	20	21	10	12	13	27
1960	39	27	31	17	18	19	43
1961	52	26	33	23	27	29	60
1962	122	34	66	23	63	43	59
1963	236	77	80	29	61	56	122
1964	373	149	157	64	88	73	172
1965	514	239	228	126	139	111	256
1966	649	332	343	204	196	185	341
1967	686	423	381	286	279	306	442
1968		454	353	368	335	475	658
1969				400		691	829
1970						924	

Note: Blanks appear in the table since the simulation has been carried on beyond the year for which actual data was available at the time of the study.

Source: Directorate of Technical Education, unpublished documents.

and a minimum output pattern. If we combine constant upper levels of the promotion rates with lower levels of repetition rates, then the output of graduates as generated by the student flow model will be maximal. The rates given before, however, when combined in this pattern, do not always meet the natural limit that the sum of promotion and repetition rates should not exceed one. In those cases where the two rates exceed one we will adjust the repetition rate so as to satisfy this limit.

The opposite of the first pattern, consisting of constant *lower*-level choices, thus leads to a minimum output. Any other possible choice will render an output in between the margins set by the two extreme patterns of choice.

Maximum and Minimum Output Patterns

The student flow model is designed to serve educational policy makers and administrators by making it possible to simulate decisions on admission capacities. Thus one may assume certain levels of outputs and calculate backward through the model for the required inputs.

The usefulness of the model depends on its precision, largely determined by the rates applied. In this section we focus on the precision by considering the most optimistic and pessimistic assumptions on enrollment—corresponding to maximum and minimum output patterns for determining the limits of the actual enrollment. The maximum and minimum output pattern calculations are presented in Table 2.5.

From the table we conclude that

- for all four major technologies, enrollment has been near the upper-level rates in the period 1955 to 1964-65, but that the rates have been falling to average levels in the period 1964-65 onward;
- if a policy maker had used the model with average rates in 1955 to calculate the stock 1969 he would have received an estimate that was not close to reality.

The degree of precision could have been improved under the existence of the proper management information system. This system would have indicated that the average rates were too pessimistic for the period 1955-65 and would have caused the calculations to be adjusted. The necessity to organize this "feedback" from actual data to the model cannot be stressed enough as a major instrument to ensure the usefulness of the model.

TABLE 2.5

Simulation of Manpower Accumulation—Maximum and Minimum Output Pattern, Major Technologies, 1955-70

	Civil		Electrical		Mechanical		Power	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
1955	0	0	0	0	0	0	0	0
1956	0	0	0	0	0	0	0	0
1957	0	0	0	0	0	0	0	0
1958	20	8	19	8	14	5	12	4
1959	53	19	38	14	24	7	39	12
1960	148	56	63	22	34	9	69	20
1961	261	94	83	27	50	14	100	28
1962	374	130	113	37	72	21	131	36
1963	496	170	140	44	95	28	160	43
1964	503	202	165	51	124	37	204	56
1965	904	317	214	68	185	58	349	165
1966	1,321	459	307	99	305	98	589	178
1967	1,860	642	437	141	501	161	915	274
1968	2,361	797	558	175	778	248	1,321	392
1969	2,818	938	734	232	1,135	358	1,740	508
1970	3,383	1,128	997	318	1,527	473	2,239	651

TABLE 2.6

Simulated Enrollment; Distribution of Admission Capacities over Technologies as in 1968

	Lower Level				Average Level				Upper Level			
Year	Class 1	Class 2	Class 3	Stock	Class 1	Class 2	Class 3	Stock	Class 1	Class 2	Class 3	Stock
						Civil Engineering						
1968	930	370	285	1,700	971	529	341	1,720	1,013	635	396	1,740
1969	948	418	292	1,888	997	635	484	1,965	1,050	792	663	2,047
1970	948	427	328	2,079	999	662	588	2,318	1,054	827	852	2,570
1971	1,048	427	337	2,294	1,099	666	622	2,748	1,155	832	913	3,243
1972	1,055	472	337	2,514	1,111	726	628	3,199	1,172	908	927	3,959
1973	1,281	475	371	2,731	1,337	739	680	3,651	1,399	924	1,002	4,680
1974	1,713	576	375	2,971	1,780	876	696	4,138	1,854	1,095	1,028	5,455
1975		771	451	3,211		1,156	814	4,633		1,445	1,194	6,243
1976			601	3,504			1,064	5,213			1,552	7,160
1977				3,902				5,980				8,361
						Electrical Engineering						
1968	484	191	114	377	505	271	136	382	527	335	158	386
1969	507	218	130	454	532	330	217	482	560	429	308	510
1970	507	228	148	542	534	352	269	642	564	463	411	754
1971	545	228	156	642	572	356	291	840	602	469	455	1,079
1972	548	245	156	746	577	379	296	1,053	609	498	467	1,437
1973	667	247	167	849	697	384	314	1,267	729	507	493	1,801
1974	891	300	169	959	926	457	319	1,493	964	597	505	2,182
1975		401	203	1,069		601	375	1,721		783	583	2,569
1976			271	1,202			488	1,989			753	3,016
1977				1,382				2,340				3,596
						Mechanical Engineering						
1968	1,076	309	281	591	1,110	450	333	605	1,144	553	385	733
1969	1,101	484	230	740	1,157	711	393	799	1,216	913	555	1,017
1970	1,101	495	350	859	1,159	765	608	1,027	1,224	1,003	905	1,477
1971	1,215	495	364	1,043	1,274	772	673	1,382	1,339	1,018	1,038	2,152
1972	1,224	547	365	1,233	1,288	842	685	1,772	1,359	1,106	1,072	2,894
1973	1,484	551	401	1,421	1,549	857	742	2,165	1,621	1,130	1,156	3,645
1974	1,985	668	406	1,627	2,063	1,015	760	2,589	2,148	1,329	1,190	4,453
1975		893	488	1,834		1,339	888	3,019		1,744	1,375	5,275
1976			649	2,084			1,160	3,522			1,776	6,229
1977				2,420				4,183				7,474
						Power Engineering						
1968	964	323	231	705	1,000	464	279	719	1,036	554	360	733
1969	986	434	221	862	1,036	646	376	924	1,090	805	580	1,017
1970	986	444	293	1,010	1,038	686	522	1,201	1,096	858	852	1,477
1971	1,091	444	303	1,208	1,143	691	567	1,586	1,202	865	943	2,152
1972	1,098	491	304	1,411	1,156	755	575	2,001	1,219	945	963	2,894
1973	1,331	494	334	1,613	1,389	769	624	2,418	1,454	962	1,042	3,645
1974	1,781	599	338	1,834		910	639	2,868	1,928	1,139	1,070	4,453
1975		801	406	2,056			746	3,325		1,503	1,243	5,275
1976			541	2,324				3,859			1,614	6,229
1977				2,685								7,474

Note Blanks appear in the table since the simulation has been carried forward beyond the year for which projected data for admissions was available at the time of the study.

Forecasting the Future Student Flow and Manpower Accumulation

The tests of the model show that the promotion, repetition, and stock survival (one minus the attrition rate) rates have been declining in the years 1955-68 from somewhere near the upper level to somewhere near the average level. The average level proves to be a quite satisfactory choice of the enrollment rates for the years 1966-69. The forecasts thus concentrate on extrapolations of the student flow along the average level. They rely on data on the future admission capacities published by the Directorate of Technical Education.

These tables do not give any clue as to how the total admission capacity will be spread over the different technologies. For projections we assume that the distribution of the total admission capacity over the courses remains constant on the 1968 level. The enrollment and stock projections for this simulation are given in Table 2.6.

It has been shown, however, that the distribution of the "admission capacity" over the courses has been changing. We have also indicated that most often a change in the distribution occurs only by increasing the total capacity. Extreme changes in the distribution of the capacity over the courses then occur if all newly created capacity is allocated to *one* technology.

A sensitivity analysis on the distribution of the admission capacity over technologies was worked out for average output patterns. From this analysis it was apparent that if the distribution of capacity changes drastically, the projections on future enrollments have to be entirely revised.

SUMMARY

We have now shown ways to measure the student flow quantitatively through promotion, input-output, pass, repetition, and dropout rates. These measurements are useful for two purposes, as was exemplified for polytechnics: (1) to evaluate and compare efficiency in educational institutions, and (2) to project future flows of students and corresponding stocks of graduates and to simulate effects of changes in the flow rates and admissions. In the decision model for technical education, the student flow model shall be further put to work to arrive at optimal resource allocation patterns.

NOTES

1. See Russell C. Davis, *Planning Human Resource Development* (Chicago: Rand McNally, 1966); and Hector Correa, *Quantitative Methods of Educational Planning* (Scranton: Intext, 1969).

2. The efforts made by economists are generally classified under "educational production functions." For a survey article, see S. Bowles, "Towards an Educational Production Function," in *Education, Income and Human Capital*, ed. W. Lee Hansen (New York: Columbia University Press, 1970), pp. 11-61.

3. For a longer discussion of this study, see the report by J.M. Ritzen, "A Study of Polytechnics in Bangladesh" (Berkeley: Program in International Education Finance, University of California, 1974) (mimeographed report).

4. This phenomenon can be interpreted in two ways: as a result of outside influences or because of "diseconomies of scale," that is, the increase in number has produced lower internal efficiency.

CHAPTER

3

COSTS AND FINANCING OF TECHNICAL EDUCATION

DECISIONS ON COSTS AND FINANCE

A central part of planning technical education is the set of decisions that must be made concerning the levels of spending and the sources of revenue. W shall now look at this monetary aspect of education planning—that is, the con sideration of the costs and the financing of institutions of technical education

Every government, regardless of its form, must make numerous decisions on revenues and financing of the systems it contains. A first decision has to be made on whether public resources (taxes) should be made available to the system. If the system deserves public financing, a wide spectrum of choices be comes available: What should be the private contribution of the users of the service as opposed to the public one? How should the public revenues be generated? Should the system not only command public support but also require public control, then the government must decide on the extent of the capital outlays and the recurring costs of the system.

Decisions about finance and costs depend, of course, as do other government decisions, on the priorities that attach to various programs. Such priorities are set by an intricate political process and certainly do not rest on economic decision making alone. If policy makers and planners do want to weigh alternatives economically, however, they have at their disposal such methods : cost benefit and rate of return analysis that connect program expenditures wit evaluation of their successes.

In this study we concentrate on technical education, that is, education for specific vocational purpose; but the analysis of costs and finance is little

different from the study of other sectors. Compared to multipurpose education, technical education is relatively easy to evaluate as the motives involved in its establishment are relatively well defined in terms of measurable economic objectives, and the schools and programs are generally separated from the rest of the educational system. In contrast, if we were studying primary and secondary education we would have to look at a mixture of objectives—literacy, citizenship, access to the better life, etc., that are relatively difficult to measure. The external performance of the technical education system therefore needs to be assessed quite differently from other education systems. But cost and finance analysis are essentially part of the evaluation of the internal functioning of the system—and that is not very different for different types of education. An exception should be made here with respect to the possible forms of financing for technical education. The unique goal of technical education suggests the possibility that the employers of the output of technical education also pay for the training. Since the employers of technical education graduates are quite well defined, that is, modern industries, a special tax levy estimated for technical education becomes feasible. Such taxation schemes are used for example in Latin America.

FINANCING EDUCATION

There are many possible financing patterns available for any type of education. This is not the place to explore this topic in detail, as many excellent studies of school finance have been made.[1] It is important for the purposes of this study, however, to note that decisions about financing, if made with knowledge about the education process (its efficiency, throughput, applicability to its goals) can lead to wiser application of resources. To summarize briefly, the planner of schools under public control faces a number of alternatives in educational finance:

1. What should be the level of public support as compared to the private contribution?
2. Which methods are chosen to collect the private contribution; should tuition fees be levied; should the government contribution be of a "matching grant" type, prorated on the private contribution?
3. Should special taxes be earmarked for the schools considered, or should the public contribution come from the general fund?
4. How centralized should the public support be and what should be the respective financial support level at the municipal, county, state, and federal level (or comparable geographical aggregates)?

While brief, this list provides the essentials for describing a finance system as it operates, as we do for polytechnics in Bangladesh in the Appendix.

COST ANALYSIS

For rational planning purposes, detailed costs of educational programs must be calculated. The degree of detail must be sufficient to examine all important parts of a type of education such as the costs of mathematics versus reading programs for primary schools, or the costs of the electrical versus power engineering program for a polytechnic, or to compare the different schools that offer a certain program. Also these costs should be known by institute where the program is offered and by year class (grade level). Such detailed cost information can be acquired without too much difficulty if: (1) programs are distinct and facilities are not shared; (2) budgets are separated from other types of schools and therefore cost data can be isolated more easily. But if these conditions do not hold—as is usually the case—serious problems arise. Statistical estimation may be feasible, however, as we shall explore in the section on cost analysis.

Information about costs is generally provided in aggregated form—that is, by yearly expenditure for certain categories. For planning purposes, information is most valuable in terms of costs per student place or costs per graduate. If there are economies of scale, that is, advantages in larger programs, they must be recognized in order to plan for the most efficient size.

Capital and recurring costs are usually separated in school budgeting, and, in many settings, funds for capital items come from quite different sources than funds for recurring costs.

Capital costs generally include land, new construction, materials and equipment, books, and athletic equipment, those items that last more than one year. Often, however, the definition of capital costs is further confined to include only new construction and equipment that lasts at least a few years. All other costs are assigned to the recurring cost budget. Recurring costs (also called current or recurrent costs) arise every year. The largest item, by far, of recurring costs is that of teachers' salaries.

Unit Costs

The single most important type of information for educational decision making is knowledge of unit costs, that is, the costs per student and per graduate. Decisions on increasing or decreasing capacity of a certain program require accurate knowledge of the costs per student and the costs per graduate by program.

In order to arrive at the total unit costs of, say, polytechnic education, one has to calculate both capital and recurring costs per student of the polytechnics.

With the information on the student flow one can derive the unit costs per graduate from the unit costs per student. Let us first look at the simplest case, where the unit costs per student are constant over all grade levels (year classes). Multiplying the unit costs per student with the number of student years it requires on the average to turn out a graduate gives the per graduate costs. If no dropout or repetition exists, this factor is simply the number of years of the training course. Under conditions of dropout and repetition, one can compute the average number of student years from a longitudinal student flow profile, that is, the number of graduates in year t, to be denoted by O_t, the number of students in the last year class (grade n) in the same year t, the number of students in grade $n-1$ in year $t-1$ or in general the number of students in grade $n-i$ in year $t-i$, to be denoted by $En_{t-i,n-i}$. The equation for the average number of student years per graduate A is then:

$$A = O_t/(\sum_{i=0}^{n-1} En_{t-i,n-i}) \qquad (3.1)$$

Capital Costs Per Student

Undoubtedly, the attribution of the costs involved at one point in time to purchase a capital good over student generations is a most difficult procedure, in which mistakes are often made. Besides, there does not exist a unique method unless it is done ex post for a capital item that has in the meantime been replaced. It is essential for the attribution of capital costs over several generations to know the depreciation trajectory over time and the salvage value of a capital item. Since such knowledge is not available ex ante, assumptions have to be made.

Obviously, it would be erroneous to find capital costs per student by dividing capital costs of one year over the number of students in that year. Although such a method is incorrect, examples of it are frequently found, including one in Bangladesh. In our study of Bangladesh polytechnics we have learned that the Planning Department provided some statistics on per pupil capital costs in the Manpower Planning Study.[2] These statistics are calculated as follows:

1. the maximum enrollment capacity of the institution just before the commencement of the development scheme;
2. the maximum enrollment capacity after the completion of development;
3. the money spent through the development scheme is divided by the additional enrollment capacity, that is, the maximum enrollment in (2) minus the maximum enrollment in (1), to get the per capita capital costs.

The per student capital costs, in the above procedure, are the one-time equal distribution of the total additional capital costs over additional enrollment

capacity, or the capital costs per enrollment *place*. This place may be filled for many years by different students without new investments (capital costs). Hence, this procedure of calculation inflates the capital cost figure if it is taken on a per student base at a particular time.

In order to distribute the capital investment per enrollment place evenly over the students throughout the period of service expectancy of the facilities, the following approach can be used: The initial capital costs plus the maintenance and repair costs for a particular facility during the expected period of life expectancy of the facility may be divided by the total number of students served during that period in order to obtain per capita capital costs or costs for that facility, taking into consideration interest rates during the period. This is the same as taking the current rental value for a year and distributing that over the enrollments, that is, calculating the "imputed" rent per pupil. The calculation of the rental value of a capital good in a year according to the above procedure is described mathematically by the following equation:

$$R \sum_{i}^{n} (1 + r)^{i} = C(1 + r)^{n} \tag{3.2}$$

where

R = imputed rent per year (in constant prices of base year)
i = index of years, 1, 2, . . ., n
n = number of years of the facilities in service
r = discount rate (constant over n)
C = setup costs of the facilities.

This means that, if an amount of money equal to the costs of the facilities were kept in a bank for the period during which the facilities would be in service, the total amount thus obtained at the end of the period would be equal to the accumulated annual rent of the facilities over the same period and at the same rate of interest. Thus we depreciate the total cost of the capital facilities in terms of annual rent over an assumed period of life of the facilities.

The assumptions made in the calculation of the capital costs as in equation 3.2 concerning the depreciation trajectory and salvage value are that no depreciation takes place until the final year of use of the capital good, when the good depreciates 100 percent and the salvage value is zero. Alternatives to this procedure are a straight-line depreciation (with a constant annual percentage) or an exponential depreciation (where the annual depreciation rate changes over time).

Recurring Costs Per Student

Recurring costs per student are acquired more easily, if a proper bookkeeping system exists and the bookkeeping data are available. Minor problems may arise. Items to be classified as "recurring costs" may differ between institutes and programs. Certainly there is no standard definition as some include maintenance and repairs, some, equipment, some, books, and the like. Thus the first problem in discussing recurring costs is to agree on what this budget item contains. Then, in order to calculate recurring costs per student, it is necessary to agree on how to calculate enrollment figures and when recurring costs per graduate are perhaps a better basis of comparison.

It may be difficult to obtain reasonably accurate figures for technical education on recurring costs per student by program and its components since separate financial records may not be kept for separate programs, and definitions of categories of spending differ.

Although the same facilities may be used by different programs, another source of difficulty in comparing unit costs exists because there may not be data on how much each program uses the common facilities. Dividing costs of shared facilites equally between categories of users may lead to inaccuracies. We will now explore a statistical method to decompose total costs into unit costs per program per student if no detailed cost data are available. In order to do this estimation, it must be assumed that recurring costs are additive, that is, that the total costs equal the sum of the parts or the separate budgets by technology. Additionally, it may be assumed that the foundation costs are the same for each institute considered.

If, in total, m programs have been distinguished, then

$$RC_i = \sum_{k=1}^{m} R_{ik} + RC_o \tag{3.3}$$

where

RC_i = total recurring costs of institute i
R_{ik} = costs of program k in institute i
RC_o = overhead costs, independent of enrollment or of institutes.

It is possible to specify other relationships between the total costs—for example, assuming complementarity rather than additivity. This we have not done here. If no economies or diseconomies of scale exist, then in the long run the average and the marginal costs per student would be equal and independent of the number of students enrolled. The total costs of program k would be equal to the number of students, E_{ik}, in that program multiplied by the costs per student, or

$$R_{ik} = E_{ik} r_k \tag{3.4}$$

where r_k are the costs per student in technology k. Inserting equation 3.4 in 3.3 gives

$$RC_i = \sum_{k=1}^{m} E_{ik} r_k + RC_o \tag{3.5}$$

In equation 3.5, the values of RC_i, total recurring cost for institute i, and E_{ik}, number of students in institute studying in program k, are known. The parameters, r_k, costs per student in k ($k = 1,2,3, \ldots, n$), and RC_o, overhead costs, are the $(n + 1)$ unknowns to be estimated.

Thus we consider every recurring cost figure of an institute to be an observation of a process of cost formation of the following nature:

$$\begin{aligned}
Y_1 &= c + x_{11}a_1 + x_{12}a_2 + \ldots + x_{1m}a_m + u_1 \\
Y_2 &= c + x_{21}a_1 + x_{22}a_2 + \ldots + x_{2m}a_m + u_2 \\
&\ldots \quad \ldots \quad \ldots \\
&\ldots \quad \ldots \quad \ldots \\
&\ldots \quad \ldots \quad \ldots \\
Y_n &= c + x_{n1}a_1 + x_{n2}a_2 + \ldots + x_{nm}a_m + u_n
\end{aligned} \tag{3.6}$$

or in vector form:

$$\underline{y} = c + X\underline{A} + \underline{u} \tag{3.7}$$

where

x_{ik} = E_{ik} and $\underline{x}$ is an $\underline{n} \times \underline{m}$ matrix
a_k = r_k and $\underline{a}$ is a column vector of dimension $\underline{m}$
Y_i = RC_i and $\underline{y}$ is a column vector of dimension $\underline{n}$
c = RC_o

while

u_i = disturbance term and $\underline{u}$ is a column vector of dimension $\underline{n}$
m = number of programs
n = number of polytechnics observed.

Now we have translated the problem of calculation of the recurring costs per student per program into a linear, multiple regression problem.

Since the original assumption of no overhead costs is unrealistic, we can now allow for the actual economies or diseconomies of scale in costs per program k mathematically by an elasticity factor b_k such that

$$R_{ik} = r_k E_{ik}^{b_k} \tag{3.8}$$

where r_k is a constant. The number of institutions in the sample places restrictions on the number of variables to be estimated. It will therefore often be necessary to assume the same elasticity b for all programs.

This elasticity can be considered a scale factor. It represents the percentage change in the costs of program k in institute i when the enrollment changes by 1 percent. If b_k is greater than one, diseconomies of scale exist; when b_k is less than one, marginal costs per student decrease with the number of students enrolled. In the section entitled "Private Costs of Diploma Students" we shall use this technique of estimating costs for Bangladesh polytechnics.

BANGLADESH: EXPENDITURE DATA

Capital Cost Data

Most data available on the costs of polytechnics are accounting data, compatible with the finance process, described more in detail in the Appendix. The most reliable but least useful data are the aggregate statistics from annual plans on capital allocation to the polytechnics and amounts spent during previous years.

There are no published data on these amounts detailed by item nor by individual polytechnic. Such data are not part of the accounting structure. The only reliable regular source of detailed information is the Communications and Buildings Department and the Supply Directorate.

Recurring Cost Data

Recurring cost data are kept at the source of spending, that is, the individual polytechnic. The polytechnics, however, only keep data specified by item, not specified by program. Within the premises of the polytechnics a range of programs is offered: diploma courses of three years' duration in several technologies, certificate courses of two years' duration in several technologies, and sometimes also a variety of one-year courses. The mix of student participation

in the different programs varies throughout the polytechnics. No separate financial record is kept for these separate programs.

Unfortunately the definitions of categories of spending varies among the polytechnics, which complicates comparisons between the costs of different polytechnics. Additionally these definitions vary within the government bureaucracy and thus recurring cost data from different sources on the same item are different. This fact explains part of the internal inconsistency in some of the sets of figures reported.

Data Sources

Three sources of data were used in this study. Data on total expenditures per polytechnic were taken from the annual plans of the Planning Department. More detailed data on finance was available from a survey of the polytechnic institutes conducted by the Institute of Education and Research (IER), University of Dacca, in 1968-69. The questionnaires of this survey (for 1964-67) were made available to us as an alternative source of data from the polytechnics. As a third source the Manpower Planning Report was available. In this report, data on capital and recurring costs per student are available.[3]

Information from the IER survey was several years old but we had to depend chiefly on this source, since it was the only one available on the financial aspects of the individual polytechnics. Although the returned questionnaires were helpful in our study, they would be quite inadequate for specific decision making for polytechnic planners.

PER STUDENT AND PER GRADUATE COSTS

Capital Expenditures

Capital costs include new construction and expansion of physical facilities like buildings, land, etc., instructional materials and equipment, library books and materials, and athletic equipment. Any other categories of expenditure except for the purchase of land have been classified in the recurring budget. Costs of the purchase of land are excluded from our cost calculations. To the best of our knowledge no records of these land purchases for polytechnics are available.

In the annual plans of the Planning Department of the government of East Pakistan (now Bangladesh), allocations for all development projects (that is,

capital investment projects) dealing with polytechnics are mentioned. The annual plans do not mention for what purpose or on which items these resource allocations were made nor is any other such information found to be published.

Yearly capital expenditures may vary greatly among polytechnics because of differences in investment schedules under which the polytechnics were established and expanded and differences in treatment of data. Moreover, if one compares actual capital expenditure to allocations made to the polytechnics during the Third Plan, a wide discrepancy is observed. In the Third Plan, for example, for 1965-70 for 15 selected polytechnics studies, 46 percent of the total amount allocated was spent. This proportion varied from 9 percent to 102 percent for individual polytechnics during that period. Several reasons account for these discrepancies:

1. Although allocated in the plans, the capital was not always made available at the critical stages of construction or purchase of equipment, thus leading to delays and, in the longer run, to low rates of actual expenditure as a proportion of allocated funds.

2. During the plan periods, resources for education were often diverted to other sectors.

3. There was a basic incapacity of the individual polytechnics and the system to absorb funds allocated, because of inadequate organization or simply overallocations.

Using the analysis of the section called "Cost Analysis," we compute capital costs per student and per graduate under the assumptions that the rate of interest is 5 percent per annum and that the average length of service of educational facilities is 40 years and 30 years.

The capital cost data of the Planning Department of the government of East Pakistan (now Bangladesh) have been used for the computation of imputed rental values. The per-pupil cost figures on different items of capital costs obtained by the above procedure are shown in Table 3.1. It is interesting to compare these with the per-pupil costs for buildings and equipment in terms of imputed rent for the Engineering diploma education in India, which was only 166 rupees (Rs.166) in 1965-66. (Indian and Pakistani currencies in 1965 were similar; in both countries the rupee was roughly equivalent to $.20.)

The transformation of per-student to per-graduate capital costs requires knowledge of the average number of student years it takes to produce a graduate. The duration of the diploma courses is three years, but, during the program, many students drop out, while others repeat. We find that, for every 34 students graduated in 1969, 225 enrollment places were occupied during the period 1966-69.[4] This means an average of 6.6 enrollment places per graduate.

All figures of Table 3.1 are to be multiplied with this factor 6.6 in order to arrive at the "per graduate" capital cost figures. Table 3.2 shows the resulting statistics.

TABLE 3.1

Per-Pupil Capital Costs for the Polytechnics
(in rupees)

	Books	Equipment	Furniture	Construction	Total
Per student place capital cost	77.64	444.42	306.47	6,090.47	6,919.00
Imputed rental value per student on:					
40 yrs. life	4	25	17	338	384
30 yrs. life	5	28	19	377	429

Source: Manpower Planning in East Pakistan, Planning Department, Government of East Pakistan (Dacca: East Pakistan Government Press, 1969).

TABLE 3.2

Per-Graduate Capital Costs for the Polytechnics
(in rupees)

	Books	Equipment	Furniture	Construction	Total
Per graduate place capital cost	512.424	2,933.172	2,022.702	40,197.102	45,665.40
Imputed rental value per graduate on:					
40 yrs. life	26.4	165.0	112.2	2,230.8	2,534.4
30 yrs. life	33.0	184.8	125.4	2,488.2	2,831.4

Source: Calculated from Table 3.1 by multiplying respective figures by 6.6.

TABLE 3.3

Recurring Expenditures of Polytechnics for Selected Years (in rupees)

1964-65	1965-66	1966-67
4,725,705	4,614,227	4,575,521

Source: IER Survey and Economic Survey of East Pakistan, 1967.

For more detail, see J. Ritzen, "A Study of Polytechnics in Bangladesh" (Berkeley: Program in International Education Finance, University of California, 1974) (mimeographed report).

Recurring Expenditures

Recurring costs include the following: maintenance and repair of existing facilities, salaries of teaching, administrative and other nonteaching staff, financial aid to students, contingency, and other costs not covered by the capital costs. An overall idea of the magnitude of the recurring expenditures of the polytechnics—the total recurring expenditures—may be obtained from Table 3.3.

In order of magnitude, salaries, financial aid, and maintenance and repair are the three largest expenditure categories. They account for between 40 percent and 70 percent of the total recurring expenditures. The amount not accounted for by the three major categories generally is by and large found under "contingencies." Note that the expenditures in Table 3.3 are by polytechnic; this means that expenditures on nondiploma courses are included.

The largest single item of the recurring budget is the salary of the teaching, nonteaching, administrative, and other personnel involved. Table 3.4 shows the amounts spent on salaries as a percentage of the budget for the three years 1964-67. This percentage increased substantially during the period 1964-67 from 35 to 58 percent and seems to be mostly a result of the decrease in the absolute figures on total recurring expenditures of Table 3.4.

Financial aid to students is another big item of recurring expenditure, as Table 3.4 shows. The figures for 1966-67 are lower than 1965-66 because a large proportion of the student aid was canceled in that year in reaction to student strikes. The percentage of students receiving financial aid varies considerably across divisions. The students who enjoy scholarship support sometimes receive more than one type of aid. Although most of the aid comes from the Public Fund in the form of DTE scholarships, local governments such as district councils and municipalities also offer certain scholarships of relatively small amount to a limited number of students of the respective districts.

TABLE 3.4

Percentage of Recurring Cost Budget of Polytechnics Represented by Various Components, 1964-67

Years	Salaries	Maintenance and Repair	Financial Aid	Other
1964-65	35.0	0.5	6.3	58.2
1965-66	50.0	1.9	6.7	41.4
1966-67	58.0	5.2	5.1	31.7

Source: Calculated from IER survey.

The proportion of maintenance and repair costs to the total budget of recurring costs has also been increasing during the period of reference, 1964-67. Comparison of such maintenance costs may be difficult between polytechnics since in some budgets these are called "maintenance and repair" and in others "contingency" items. For any one polytechnic, there is an internal consistency in budget categories, but not between polytechnics, and one must approach such comparisons with care.

The per-student recurring costs for all polytechnics are shown in Table 3.5 ι major expenditure item. In the table, Planning Department figures are also included. The figures obtained from the IER survey are higher than those of the Planning Department except for "maintenance and repair." Recurring costs per graduate for each year were computed by dividing total recurring costs by the number of graduates for each of those years. The result is recorded in Table 3.6. It appears now that the ratio of costs per graduate to costs per student is higher than the 6.6 figure used in the preceding section for most years; for example, the ratio for 1964-65 is here approximately 7.4. This difference is a ·.sult of increasing enrollments during the period 1964-67 and the method used in making computations. Under such conditions of increasing enrollment the ratio of the total of the sum of (enrollment of the first-year class in year $[t-2]$ + enrollment of the second-year class in year $[t-1]$ + enrollment of the third-year class in year t) to the number of graduates in year t, which was computed above, will always be smaller than the ratio of the total enrollment over all year classes in the same year to the number of graduates in year t.

Comparisons of per-pupil and per-graduate costs for both recurring and capital expenses give an impression of the tremendous wastage in polytechnics resulting from the low throughput. Because of this wastage, the average costs of producing a graduate are approximately Rs. 2,500 in capital costs and Rs. 8,000 in recurring costs, or, in total, about Rs. 10,500. Computations of recurring cost per student were also made by polytechnic and showed substantial variation between institutions.

TABLE 3.5

Per-Pupil Recurring Costs for All Polytechnics Combined by Major Item, 1964-67 (in rupees)

Year	Personnel	Maintenance, Repair, and Operation	Others	Total
1964-65	481	7	875	1,363
1965-66	585	22	551	1,158
1966-67	582	52	372	1,006
Overall	554	29	577	1,160
P.D. 1967-68*	470	69	459	998

*Planning Department data.

Source: IER survey.

TABLE 3.6

Per-Graduate Recurring Costs for the Polytechnics, 1964-67 (in rupees)

Year	Ratio of Per-Graduate to Per-Student Recurring Costs	Personnel	Maintenance, Repair, and Operation	Others	Total
1964-65	7.4	3,577	51	6,513	10,141
1965-66	7.4	4,353	167	4,089	8,609
1966-67	6.3	3,650	328	2,333	6,311
Overall	6.9	3,848	204	5,034	8,058

Source: Calculated from Table 3.5.

ECONOMIES OF SCALE

In the section called "Cost Analysis," a statistical technique was described for estimating the costs per program. This technique of regression analysis produces results from which it is possible to determine whether the costs per program among institutions are alike or not. If the costs are alike, then the exact level of these costs can be established with the technique. And if they differ, this result in itself has policy implications. The planner must then examine why certain institutes maintain costlier programs than others.

Since neither individual polytechnics nor the DTE keeps expenditure records separately by program costs per student per technology (certificate versus diploma and/or by different types of diploma courses), we apply here this estimation method. The elasticity coefficients that were assumed to be the same for all technologies were chosen differently in a set of four estimations. The first value chosen for the elasticity was one, which implies no economies or diseconomies of scale. Subsequent values for the elasticity were chosen in the direction where improvements in the statistical results were expected.

The elasticity of .425 was estimated statistically by using total enrollments and total cost data for 16 institutes and three years. This coefficient was found to a significance level of .9995 and with the constant factor (foundation costs) of 23,000.

Data on enrollments and recurring costs of three different years from only seven polytechnics were used for regression analysis.[5] The other polytechnics were excluded from the sample as inconsistencies were found in the recurring costs data of these institutes. A computer program was made available from the School of Business Administration of the University of California, Berkeley, for regression analysis.[6]

Throughout these statistical analyses, it was constantly assumed that only the diploma students claim recurring expenditures; in other words, that the cost requirements by the certificate students can be ignored. This assumption was justified because: (1) the costs per student in certificate courses are actually much lower than those in diploma courses; and (2) the enrollment in certificate courses is very small.

For all years combined, two separate sets of results are given: one in which overhead costs or foundation costs were considered to be zero and another in which these costs--assumed to be the same for all institutes—have been estimated.

The results of these regression analyses are presented in Table 3.7. It may be surprising to note that some of the regression coefficients are negative, which would imply that a decreasing expenditure is associated with an increase in enrollment. Average and marginal costs per student are always nonnegative.

TABLE 3.7

Regression Analysis of Cost Data, 1964-67

Coefficient for Technology	Linear Regression (no economies of scale)		Elasticity .5		Elasticity .333		Elasticity .425165	
	No Foundation Cost	Foundation Cost	No Foundation Cost	Foundation Cost	No Foundation Cost	Foundation Cost	No Foundation Cost	Foundation Cost
Foundation costs	0	220,206[a]	0	142,343	0	84,840	0	120,048
Civil	1,414[a]	214	18,134	8,911	37,807[a]	26,464	25,403	14,567
Electrical	-1,390[b]	1,241	-5,333	8,600	371	15,759	-4,297	11,340
Mechanical	807[b]	255	12,387[a]	7,336[b]	29,595	22,307[b]	18,348[a]	11,996[b]
Power	796[b]	-336	4,612[b]	- 2,185	9,447[b]	707	6,239[b]	- 1,815
Others	- 1,111[b]	1,108	11,710[a]	16,831[a]	40,672[a]	43,840[a]	21,362[a]	25,962[a]
Number of observations	21	21	21	21	21	21	21	21
Standard error	116,714	27,849	79,065	78,018	75,302	77,186	76,768	77,393
R squared	.8116	.9000	.9135	.9211	.9216	.9228	.9195	.9223

[a]Statistically significant, .995 level.
[b]Statistically significant, .90 level.

Additional enrollment cannot lead to decreasing recurring expenditure.

Negative costs per student may have arisen for the following reasons: (1) the data used are not correct; (2) the relationship between the recurring cost and enrollment is not as specified; (3) the relationship of recurring costs to number of students not only differs from technology to technology, but also differs vastly from one polytechnic to another; and (4) foundation costs are not the same for all polytechnics. The best results are found for the elasticity of .333. All coefficients are positive. Also the square of the multiple regression correlation coefficient (R squared) is among the highest, while the standard error is minimal among the four elasticities considered, for the estimation with zero foundation costs.

The results from the statistical procedures seem to indicate that strong economies of scale prevail, which means that the marginal costs per student decrease with the size of the enrollment. We conclude that for the type of relationships between total recurring costs and enrollments investigated, the marginal and average costs per student vary widely for the technologies considered.

PRIVATE COSTS OF DIPLOMA STUDENTS

Student tuition fees are the same in all the polytechnics and in all courses. But other fees—mainly consisting of examination fees, excluding hostel fees—vary considerably from institute to institute. The fees were in 1967-68:

Tuition fee	Rs.60.00 per year per student
Other fees (average)	Rs.31.31 per year per student

The distribution of "other" fees, which includes examination fees and other academic fees, ranges from Rs. 9 to Rs. 58 with a standard deviation of 11.93. This fee does not include living expenses and hostel fees.

Student fees constitute income to the polytechnics, although in an insignificant amount compared to total expenditure. Money collected goes to the Central Government Treasury, and is thus not to be used by an individual polytechnic.

These fees are not the only expenditures paid by students. Besides expenses for books and stationery, many students incur the cost of hostel accommodation or outside living expenses and suffer the opportunity costs of income foregone while at school. On the other hand, employment opportunities for SSC or HSC graduates are few and a sizable proportion of the students enrolled in polytechnics are able to acquire scholarship support for part of their direct expenses.

SUMMARY

In this discussion of costs of education, we have derived techniques to compute unit costs. These unit costs include capital and recurring costs and are considered to be the single most valuable piece of information on costs for a decision model. Unit costs can be computed on a per-student and a per-graduate basis.

In order to compute the unit costs by program, we found the need to develop a statistical technique to decompose the total costs of an institute into the costs per program. Economies of scale in educational institutions were explored.

The framework for cost accounting developed in this chapter will be further used in the decision model in Chapter 5.

NOTES

1. See, for example, Charles Benson, *The Economics of Public Education*, 2d ed. (Boston: Houghton Mifflin, 1961); and Manuel Zymelman, *Financing and Efficiency in Education* (Boston: The Nimrod Press, 1973).

2. From the report, *Manpower Planning in East Pakistan*, Government of East Pakistan, Planning Department (Dacca: East Pakistan Government Press, 1969).

3. Ibid.

4. See Figure 2.3 in Chapter 2.

5. The data have been acquired from the IER survey; the enrollment data for polytechnics are usually obtained as combined enrollment for all technologies in the first-year class and separate for the second- and third-year classes. In order to obtain enrollments by technology for a polytechnic, we split the enrollment in the first-year class to the different technologies offered in that polytechnic according to the existing ratio of enrollments in the second- and third-year classes combined in respective years. The polytechnics chosen are Barisal, Bogra, Chittagong, Dacca, Faridpur, Mymensingh, and Sylhet Polytechnic Institutes.

6. The program is TSP, version of March 29, 1970, processed with the CDC 400 computer of the University of California, Berkeley.

CHAPTER

4

EMPLOYMENT AND EARNINGS OF TECHNICAL SCHOOL GRADUATES

MARKETS FOR EDUCATIONAL OUTPUTS

A basic prerequisite for the planning of a system is information about the performance of the system. The preceding two chapters have dealt with internal operating characteristics of the technical education system. But so far we have not examined technical education vis-à-vis the labor market. We shall consider the employability of graduates to be the criterion for the measurement of the performance of a technical education system. This is in line with the relatively quite explicit and singular goal of technical education as an instrument to provide trained manpower. Other types of education typically are not set up with a single goal in mind, nor are the goals explicit.

For the purpose of judging the performance of technical education, in terms of the employability of its graduates, the following questions should be asked:

1. Do the graduates of the educational institution find employment within a reasonably short period of time?
2. Are the employment positions that these graduates find in line with their training, or do those positions demand less skill and knowledge than the training provides for?
3. What is the incremental earnings stream associated with that particular level of education?

Not only are the absolute answers to the first two questions important, but it is also relevant to know what the changes in the employment possibilities and in earnings have been over time. To consider the change over time in the

rate and period of unemployment, and in the rate of underemployment, the employment position of graduates of different years has to be considered.

Information on the earnings of graduates enables the analyst to apply investment analysis to education. The total training costs—including the opportunity costs of foregone earnings—can be viewed as an investment in the potential "human capital" value of the individual. The payoff of this investment is increased productivity. From economic theory we know that under conditions of perfect competitive market equilibrium, the wages of a worker equalize his marginal productivity. Neither perfect competition nor market equilibrium can be assumed in a developing country like Bangladesh. Nevertheless, wages are the only variable on which information can be found (without going through elaborate measurement procedures) to assess productivity. The payoff from the investment is then the increment in the wages resulting from the addition in training. A measure by which the "profitability" of investments in that education can be compared with investments elsewhere is the internal rate of return. The internal rate of return is the discount rate, applied to the incremental wage stream, for which this discounted earnings stream equalizes the costs of education, or

$$C = \sum_{i=1}^{n} (IW_i)/(1 + r)^i \qquad (4.1)$$

where

C = the total costs
IW_i = incremental wages in year i
r = internal rate of return
n = life span of the individual

To compute the social rate of return (in contrast to the private), wages before tax are used as a measure of the societal benefits from the investment in education. If the societal rate of return for the "average" graduate of the particular type of education considered exceeds the corresponding rate of return to alternative investments, one can say that the investments in that level of education were well made.

While such information on the social rate of return and on the employment conditions may be sufficient to assess whether the best performance of the technical education system is satisfactory or not, it does not directly indicate to the planner the changes to be made to improve the external efficiency of technical education. For that purpose a substantial amount of analysis and interpretation of the data needs to be done, as we shall explore in the subsequent section.

SUPPLY OF MANPOWER, EMPLOYMENT, AND WAGES

To interpret what a particular pattern of starting wages, rate of return, or employment characteristics mean, one needs to consider the effect of the supply of one kind of manpower on wages and unemployment.

If the supply of graduates has increased, one expects from economic theory that, in the long run, wages fall until the demand for graduates has adjusted to supply. In the process, however, individuals may experience spells of unemployment on the one hand, while on the other hand the equilibrium position between demand and supply could include considerable underemployment (or employment outside the field for which the graduate has been trained). The basic assumption is then that it takes time before wages adjust to the existing demand-supply conditions.[1] During the adjustment process the demand-supply conditions may once again have changed such that the wage equilibrium position based on the past demand and supply conditions may not allow for full employment, or in the opposite case of undersupply that the demand cannot be satisfied.

But periods of unemployment after graduation occur independently of the demand supply conditions—the so-called frictional unemployment. Graduates like to "shop around" to find the job that suits them best, whether in salary, employment conditions, type and place of work, or otherwise.[2]

A surprising phenomenon in South Asia is that wherever unemployment of educated labor occurs, it occurs mostly after graduation. The time periods of unemployment, however, are too long to be realistically viewed as compatible with "job search." From all evidence it appears that once a graduate is employed he is not likely to become unemployed afterward. "Laying off" of older trained workers seems not to occur. Also the chances for a graduate to find a good job do not seem to decrease with an increase in his period of unemployment after graduation.

That older workers are not laid off might be explained as follows: There may be very few older workers with education, since the educational system in its present size is relatively young. In addition, it is widely held that the quality of education decreased during the explosion in enrollments, so that the qualifications of the older part of the labor force is superior to that of the junior part.

But that the type of job open to a graduate would be independent of his period of unemployment is puzzling. That finding implies that employers accept applicants regardless of their period of unemployment—and the consequent freshness of their training. It has been suggested that this is a cultural effect: Age seniority is regarded as a positive attribute, outweighing the negative effects of not being employed. But if this were true, it would pay off for potential students to delay entrance into technical education and gain seniority while

working, but there is little evidence of this. In short, this puzzle remains unsolved.

While the preceding may sketch the background for the analysis of earnings and employment, this background merely provides the hypothesis to be tested for a particular case study. To be more specific, if unemployment is found to occur, it is important to examine whether the period of unemployment after graduation affects the wages of the graduate. If this is not the case when unemployment occurs, then it becomes more likely that a queuing process may be taking place, in which the graduates who have been unemployed longest get jobs first and in which fresh graduates join the queue, waiting for their "turn" for employment.

Before that problem can be analyzed it is necessary first to get a general idea of the employment market by considering whether starting salaries changed over time and whether the period of unemployment has increased, decreased, or remained unchanged. Also one would like to get an aggregate variable of unemployment, over all graduating classes, and to compare unemployment rates of specific types of manpower. If periods of unemployment have changed over time, such comparisons are difficult with that variable alone. It is possible to construct a rate of unemployment from data on periods of unemployment. The supply of graduates can be fitted into a smooth curve and so can the number of graduates employed (demand). To fit the demand into a smooth curve it is necessary to know the total number of graduates employed at one point in time and the frequency distribution of the periods of unemployment specific by the year of graduation. This is elaborated further in the section entitled "Stock of Employed and Unemployed Graduates."

An important part of the analysis of the employment characteristics is to identify the variables, not related to aggregate supply and demand, that affect the employment position of an individual. Such variables could be the grade-point average received at graduation, the pretraining academic background, the relative "influence" of the father or guardian (approximated with his wage and education level), etc. In the section entitled "Earnings Function Estimated," we give attention to the relation between these personal attributes and the employment position for the case study.

The aims of an employment study of one type of graduate can now be summarized to be as follows:

1. To estimate the levels of unemployment over a specified period;
2. To assess the salary structure;
3. To survey the employment opportunities by places of employment and mobility;
4. To identify the determinants of employment characteristics, particularly of the period of unemployment on earnings;
5. To consider the impact on employment of personal attributes, such as academic background, grade-point average, and home background on employment.

The information to be collected concerns three sets of variables:

- Employment characteristics (period of unemployment after graduation, present employment status, durations, places and employers of jobs held);
- Education and ability variables concerning the pretechnical training academic background, and the grade score in the technical training.
- Background variables (father's educational background and salary).

EMPLOYMENT AND EARNINGS OF POLYTECHNIC GRADUATES IN BANGLADESH

The Survey

No accurate statistics were available on the variables mentioned in the preceding section for assessing and analyzing the polytechnic graduates' employment characteristics such as salaries, terms of employment and unemployment, and their relation to background and ability variables. This information was therefore collected by means of a sample survey of graduates. The survey was accomplished by mail in two stages. In the first stage, the sample chosen was reduced to an effective sample of graduates by requesting returned cards with current addresses. In the second stage, employment information was collected from the effective sample by questionnaire. The universe included diploma course graduates from government polytechnics of the years 1963-69, that is, all graduates of the years 1963-67 and all graduates of a selected group of five polytechnics for the years 1968-69. The 1963-67 universe was collected earlier by the Institute of Statistical Research and Training of the University of Dacca.[3] The survey was conducted between October 1970 and March 1971, during the prelude to Bangladesh's independence. Table 4.1 shows respondents by universe, while Table 4.2 indicates the response rates in the two successive stages. It can be seen from Table 4.2 that in the first stage a considerable number of cards requesting address and employment information were sent back stating "address unknown," and generally more for earlier than the later years. Over all years, less than 30 percent of the address-requesting cards were not returned. The percentage of questionnaires returned is particularly high in view of the extremely difficult situation of the postal system at the time of the survey; a postal strike occurred in February 1971 and was followed in March by a complete standstill of the mail during the Non-Cooperation Movement.

The lower response rates to the questionnaire for the 1968 and 1969 sample of polytechnic graduates is explained by the fact that all graduates in the 1963-67 effective sample received questionnaires before January 1, 1971, while most graduates in the 1968-69 effective sample were not sent a questionnaire until

TABLE 4.1

Number of Respondents and Universe by Year of Graduation and by Course, 1963-69 (universe figures in parentheses)

	Year of Graduation							
Course	1963	1964	1965	1966	1967	1968[a]	1969[a]	Total
Civil	2	13	7	3	15	10	11	61(1,670)[b]
Electrical	4	3	3	7	2	21	19	59(363)
Mechanical	4	0	1	4	7	11	12	39(587)
Power	2	5	4	7	3	13	12	46(592)
Others	0	0	0	0	3	4	2	9(195)
Total	12	21	15	21	30	59	56	214
	(442)	(358)	(438)	(523)	(687)	(600)	(367)	(3,415)

[a]The universe of the years 1968 and 1969 is made up of the output of five polytechnics only.

[b]Universe figures are in parentheses.

TABLE 4.2

Percentage of Graduates' Response to Cards and Questionnaires by Years of Graduation, 1963-69

	1963	1964	1965	1966	1967	1968	1969	Total
Percent return of cards requesting current addresses	36	72	37	62	64	77	74	66
Percent of returned questionnaires to effective sample	81	76	97	65	94	49	54	64

late January, that is, on the brink of the breakdown of mail communication.

The conscious nonresponse to the cards requesting addresses and employment status—the first stage of the survey—must be considered to be small. Whether these conscious nonrespondents have one or more traits of background, mobility, etc., in common is unknown. Hence we are not certain whether in fact the effective sample of graduates is fully random. Response to the questionnaire in terms of the effective sample for those graduated during 1963 and 1967 is very high. It is impossible to estimate the percentage of the deliberate nonrespondents of the effective sample of those graduated in 1968 and 1969, as compared to the percentage of those who did not receive the questionnaire or whose replies were never received due to the disturbances.

In all we must conclude that insufficient checks have been made to assert that the respondents are truly representative for the universe. However, the figures in Table 4.2 suggest that with some caution we might consider as representative the respondents of the years 1963-67 and those with diplomas in civil, electrical, or power technology.

Unemployment

In both stages of the survey, information on the employment position of the graduates was sought. On the card requesting addresses of the first stage the graduate was asked to mention whether he was employed or not. Detailed information on both unemployment and employment outside their field of training was sought in the second stage through the questionnaire. Employment was defined as holding a regular full-time job. Employment "outside the field of training" was not defined more explicitly in the questionnaire, and answers may reflect different notions of "the field of training." One important variable concerning the employment position is the period of unemployment.

Table 4.3 contains the distribution of replies to the question on the time lag between *receiving the diploma* and the first job. (The period between the examination and receiving the diploma has not been counted. The latter period ranged in the years 1963 to 1970 from 2 to 5 months.) From the table it appears that the time lag between receiving the diploma (graduation) and the first job has increased in time. The contrast between the frequency distribution of this period of unemployment for the earliest two years of the survey, 1963 and 1964 on the one hand, and the two last years, 1968 and 1969 on the other, is particularly sharp. While no one who graduated in 1963 or 1964 was unemployed for more than nine months, more than 30 percent of those graduated in 1968 and more than half of those graduated in 1969 were unemployed for more than nine months. No graduate appears to have become unemployed after once having been employed.

Period of Unemployment between Receiving Diploma and First Job, by Year of Graduation, 1963-69 (number of graduates)

Year of Graduation	Period of Unemployment									
	Less Than 3 Months	3-6 Months	6-9 Months	9-12 Months	12-15 Months	15-18 Months	18-21 Months	21-24 Months	More Than 24 Months	Total
1963	12	0	0	0	0	0	0	0	0	12
1964	14	5	2	0	0	0	0	0	0	21
1965	6	2	3	3	0	0	0	1	0	15
1966	10	9	2	0	0	0	0	0	0	21
1967	13	6	7	1	2	0	0	1	0	30
1968	26	6	6	3	3	1	7[a]	1[a]	6	59
1969	7	2	13	20[a]	14[a]	dna[b]	dna	dna	dna	56
All years	88	30	33	27	19	1	7	3	6	214

[a]Graduates who were unemployed at the time of the survey. The periods of unemployment for such DLE's, graduated in the same year, need not be equal since examinations are held twice a year.

[b]dna = does not apply, since this survey was made for August 1970; 1969 graduates could not, at that time, be unemployed for more than 12 months.

None of the respondents graduating before 1968 reported being unemployed at the time either in the first or second stage of the survey, but unemployment among 1968 and 1969 graduates was considerable. For 1968 graduates the percentage found unemployed in August 1970 was 31 in the first stage of the survey and 27 in the second stage. For 1969 graduates these percentages are as high as 78 and 62, respectively. The difference between the percentage found in the first stage and that of the second stage is an important indicator of the degree of bias incurred in generalizing the result of the effective sample. The unemployment rates of the respondents to the cards requesting addresses are somewhat higher than for the respondents to the second stage of the survey. It appears, however, that the differences in unemployment rates for the two stages of the sample are too small to lead to bias in generalizing the second-stage respondents' characteristics for the full sample as far as unemployment and related variables are concerned. Then we must conclude that the sustained growth in the polytechnics' output has put a heavy strain on the employment market for graduates, and that considerable caution should be exerted in expanding polytechnics any further.

The findings on employment outside the field support this contention. It is likely that, as time passes, an unemployed graduate will attach less importance to the field of employment or to the professional standard of the job for which he is applying. In practice, increasing numbers of graduates are found working outside their field of training (in one case as a ticket seller in a cinema). From the survey it appears that 7 percent of the employed graduates considered that they remained outside their field of training for more than two years. Most of the graduates surveyed who worked outside their field did so for a period of less than two years. But the percentage of graduates employed for more than three months in other fields is substantially higher among the 1968 and 1969 graduates in comparison to graduates from earlier years. As noted, the answers to the questionnaire concerning employment outside the field of training are subjective. It is difficult to make a valid judgment on employment outside the field unless one first defines the limits of the field in formulating the question. This was beyond the scope of this survey. The evidence from the survey suggests that periods of employment, rates of unemployment, and rates of employment outside the field of training are not significantly different for those graduated from different geographical divisions in Bangladesh.

Salaries

A second aim of the employment study has been to assess the impact of the changes in the supply of graduates on their starting wages. Table 4.4 presents

TABLE 4.4

Starting Monthly Salary of the Graduates by Year of Start of the First Job, 1963-71
(number of graduates)

Salary[a] in Rs.	Year									
	1963	1964	1965	1966	1967	1968	1969	1970	1971	Total
More than 700	–[b]	1	–	1	–	–	–	–	–	2
500-700	–	1	1	1	–	1	2	–	–	6
300-500	2	–	8	6	9	9	11	8	–	53
100-300	1	4	4	2	5	17	14	8	1	56
Less than 100	–	–	–	–	–	1	–	–	–	1
Total	3	6	13	10	14	28	27	16	1	118[c]
Mean salary	Rs. 333	400	354	420	329	273	310	300	200	319
Index[e]	112.9	114.8	117.0	119.8	125.2	128.9	133.0	?[d]	?	–

[a]First salary after receiving diploma.

[b]– = none.

[c]The starting year is not known for all graduates in the sample.

[d]? = not available.

[e]Index of per capita gross income at constant factor costs (1959-60 = 100) from Pakistan Economic Survey 1969-70.

the findings of the survey on starting salaries by the year of the start of the first job. One cannot interpret these figures without a number of reservations. First, particularly for the years 1963, 1964, and 1971, the numbers of respondents involved are very small. Second, one notices that the table does not differentiate between technologies. Presumably since starting salaries differ by technology we can only compare the salary frequency distributions for those years for which the distribution of respondents by technology is the same. Fortunately the technology distribution of respondents is quite similar for the years 1965-70. Third, the mean salary is calculated from a discrete distribution assigning the midpoint of the intervals in each case.

When comparing 1965 to 1970 starting salaries the first two reservations can be ignored, but the third problem remains. The means (uncorrected for the upward change in the per capita income index) indicate a fall of starting salaries during that period.

Present salaries are lower for graduates of later years than for earlier ones as Table 4.5 shows. The difference in present salaries reflects the fall in starting wages as well as the increase in salary with the experience on the job.

The means of the present salaries computed by technology fluctuate between Rs. 333 (for other technologies) and Rs. 438 (power technology). Considering that (1) the mean is calculated assigning the midpoint of the interval in each case and (2) that the distribution of responding graduates over technologies has changed over the years, no inferences can be made concerning salary differences between technologies, except for power technology. Power technology graduates earn consistently higher salaries than their colleagues graduated in the same year. The frequency distribution of present salaries are not significantly different for those graduated from the four geographical divisions of Bangladesh.

Unfortunately, sufficient information was not available for computing rates of return. On the one hand, the opportunity costs of foregone income were not known for the trainees of polytechnics, while on the other, no complete age earnings profiles could be constructed with the data available from the survey or other sources known to us.

Employers and Job Mobility

A third aim of the survey was to identify the employers of polytechnic graduates. This was considered to be particularly important in view of the original goals of the establishment of polytechnics, that is, to provide the manpower for the emerging new industries. In this stage also an attempt was made to establish the preferences of graduates for different employers by identifying the direction of the job transfers.

TABLE 4.5

Present Salaries of Employed Graduates by Year of Graduation, 1963-69
(number of graduates)

Year of Graduation	Salary Scale in Rupees: More Than 900	Between 700 & 900	Between 500 & 700	Between 300 & 500	Between 100 & 300	Below 100	Total	Average Salary (in rupees)
1963	1	1	1	7	1	0	11	491
1964	2	1	4	9	3	0	19	495
1965	0	1	2	8	2	0	13	431
1966	0	0	2	15	1	0	18	411
1967	0	0	2	19	6	0	27	370
1968	0	0	1	23	17	0	41	322
1969	0	0	1	7	10	1	19	207
All years	3	3	13	88	40	1	148	381

Employment opportunities of polytechnic graduates are to a large extent restricted to government and semigovernment agencies. Of the employed respondents, 69 percent work with government and semigovernment agencies. This includes 15 percent of the respondents who teach in polytechnics. This percentage is quite high and is due to the expansion of training capacity. No graduate is found to be self-employed. Mechanical engineers work outside the government to a significantly larger percentage (46 percent) in comparison with other technologies.

Of those responding to the questionnaire, 10 percent changed their jobs at least twice, 35 percent at least once. Of the 52 who transferred, 23 remained within the government service, 5 left the government service for other employment, 13 transferred within the nongovernment sectors, and 11 transferred from nongovernment employers to government service.

SURVEY ANALYSIS

Stock of Employed and Unemployed Graduates

The frequency distribution of periods of unemployment together with our knowledge about the supply position (from Chapter 2) enables us to reconstruct an unemployment rate. This can be accomplished by fitting curves through the known supply and demand points. The curve fitting is here done in a graph (see Figure 4.1).

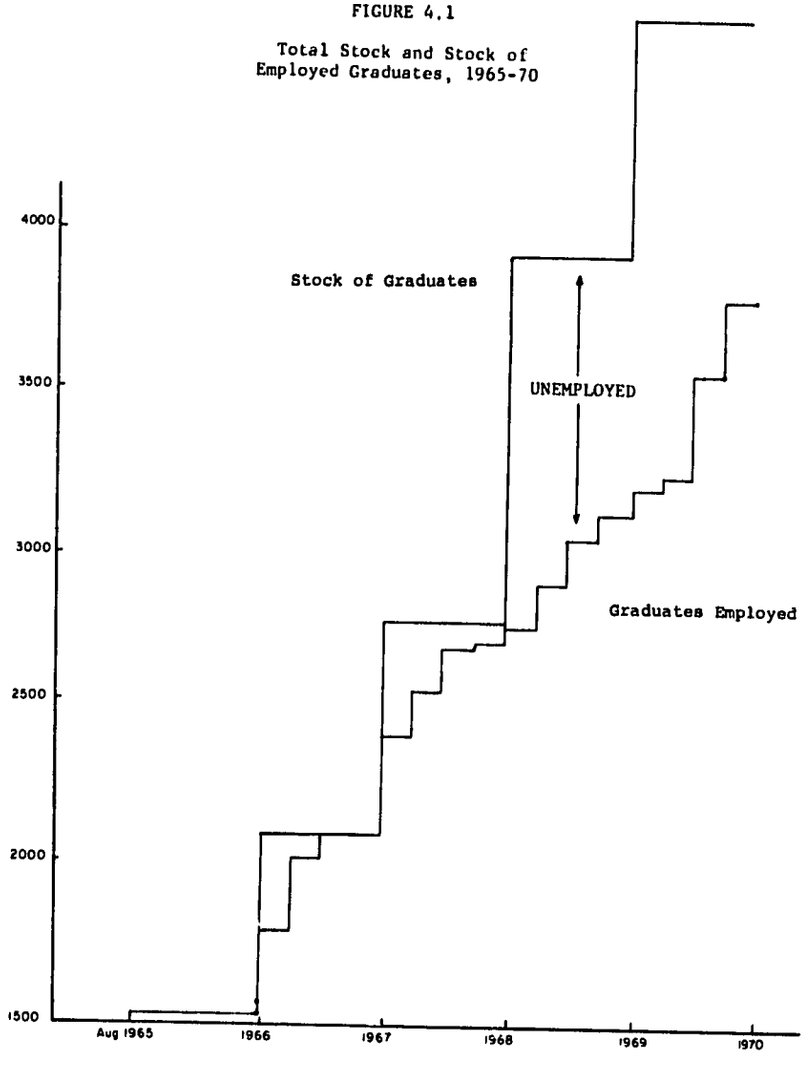
Suppose now that the percentage distributions of time lags between graduation and first employment of the cohorts 1965-70 of Table 4.3 are representative for the universe. We can reconstruct the employment position of the stock between 1965 and 1970 as follows:

1. The stock of graduates of the technologies concerned was approximately 1,560 on August 1, 1965 (civil 789, electrical 197, mechanical 207, power 316, radio and electronics 32, and chemical 23). From Table 4.3 we generalize (by assuming that the proportion of 1 to 15 holds between sample and the whole population) that approximately 6 percent (or 30) of the 1965 graduates were still unemployed as of the time the new graduates of 1966 joined the stock.

2. According to the table, and again generalizing from our sample to the whole population, 48 percent of the total of 423 graduates of 1966 found a job within three months (before November 1, 1966), 90 percent within six months (before February 1, 1967), and all within nine months (before May 1, 1966). In addition, the thirty 1965 graduates, unemployed at the time of the 1966 graduation, found employment between the 21st and 24th month after graduation, or before August 1, 1967.

FIGURE 4.1

Total Stock and Stock of Employed Graduates, 1965-70



3. Using the same data we may conclude that, on August 1, 1967, all those in the stock who graduated before 1965 were employed. Of the 753 graduates of the cohort 1966-67, 43 percent (or 324) were unemployed for less than three months, 20 percent (151) for between three and six months, 23 percent (or 173) for six to nine months, 3 percent (23) for nine to twelve months, 7 percent (53) from twelve to fifteen months, and 3 percent (23) between twenty-one and twenty-four months, if we apply the 1967 respondents' distribution to the universe. With the time lags we can determine the actual time periods in which 1966-67 graduates found jobs.

4. The same procedure then is repeated for the 1967-68 cohort and the 1968-69 cohort.

5. If we assume that all 1,560 graduates in the stock at August 1, 1965 were fully employed, we can plot for the period 1965-70 the actual stock against the stock employed, as was done in Figure 4.1. The difference between these two indicates the number of unemployed graduates.

In Figure 4.1 attrition has been ignored, since graduates were generally in the age group that would not be affected appreciably by death or retirement. From the graph it can be seen that:

- In the last few years, the average annual growth of the stock has been about 800;
- employment opportunities have increased by about 500 annually;
- thus the actual stock of unemployed graduates has been increasing by about 300 annually;
- hence the estimated unemployment by August 1970 is at least 1,000 of a total stock of 4,500.

This unemployment rate of about 25 percent equals the average unemployment rate of college and university graduates in Bangladesh.[4] It is also the same as the unemployment rate found in the manpower exercises of the Planning Department[5] even though it seems that the latter percentage is based on overestimation of both stock and employment opportunities.

Pay Scales and Promotion Possibilities

The present salary structure of polytechnic graduates in government service can be determined from the advertisements in the newspapers. It has been found that the government and semigovernment agencies maintain a fairly uniform scale for graduates of different technologies.[6] The monthly starting wages offered to a new graduate range between Rs. 210 and 300. The maximum only increases to Rs. 350, for those with two to three years of experience, while the minimum remains unchanged. For graduates with five years of experience the

range is found to be between Rs. 265 and 600.[7] Private organizations rarely advertise jobs in the newspaper but rather appear to make most of the recruitments on a person-to-person basis. During a period of five months in 1970-71, there was not a single job advertisement for a polytechnic graduate in the two leading dailies in Dacca.

The *Industrial Manpower Skills* study of the National Commission on Manpower and Education (NCME) provides information on the salary structures of private employers.[8] The salary ranges of skilled craftsmen, supervisors, foremen, assistant engineers, and draftsmen (all occupations that require a polytechnic training or equivalent), are between Rs. 250 and Rs. 550 monthly, practically regardless of the type of industry. From this comparison, it would seem that the government pay scales are above those in the private sector. The information collected, however, shows the reverse.

Compare these pay scales to the Rs. 5 to Rs. 15 daily wages of line workers and the handsome salaries in the ranges Rs. 350 to Rs. 1,500 monthly for graduate engineers.[9] Considering the starting salaries of the polytechnic graduates in Table 4.4, we find that, in the past, most have succeeded in entering directly into well-paid jobs.

Kann finds the mean of the present salaries for graduates of the electrical and mechanical technologies to be Rs. 391 and Rs. 403 respectively.[10] These figures are somewhat higher than those reported in Table 4.5, which can be partly explained by the fact that Kann only considered those who graduated from Chittagong Polytechnic between 1965 and 1968. On the other hand, our study had a fairly large number of 1969 graduates who are on comparatively low salaries.

Salaries depend strongly on the types of occupations graduates have. They have been trained for the so-called subordinate engineering service (sub-assistant engineers, overseers, foremen, etc.). The possibilities for promotion within this service are limited, however, causing widespread frustration, unrest, and pressure on employers to extend promotion possibilities to the ranks of the engineering service proper. As a result of pressure by graduates of polytechnics, a quota of 15 percent was fixed in 1964 for those graduates in the Railways, Water and Road Transport Department Engineering Service. However, this decision has never been implemented. Similar decisions were made in the Water and Power Development Authority; 25 percent of the assistant engineers in the power section and 10 percent in the water section ought to be polytechnic graduates. Promotions are rare in the polytechnics, where 15 percent of all the polytechnic graduates work as instructors or workshop superintendents, which has led to complaints. In fact, a countrywide strike of polytechnic graduates was called for March 5, 1971, to focus attention on this matter, but it was canceled at the time the Non-Cooperation Movement started.

Earnings Function Estimated

In the survey, data have also been collected on personal characteristics that were considered to have a bearing on the employment position of an individual graduate. This included information on the father's educational background and father's earnings, the age at the time of graduation, and the academic achievement (the division obtained at the diploma examination).

Attempts have been made to explain the differences in earnings and length of time of unemployment by the three sets of variables mentioned above, as well as by employment type variables.

Different theories have been developed to explain the differences in the time lag between graduation and employment in terms of the background and the academic achievement within the same cohort. Blaug contends that unemployed graduates in India accrue age seniority while remaining unemployed and thus improve their position with respect to the job market. In that view, the age at the time of graduation should have a significant impact on the period of unemployment. Others suggest correlations between fathers' income and unemployment periods, reasoning that children from richer families can better afford to wait for the "right" job, however long that may take. A third factor, considered to explain in part the differences in the period of unemployment within the same cohort, is the grade or division obtained at the diploma examination.

These hypotheses have been statistically tested using the data from the 146 employed respondents to the survey. These belong to different cohorts, all of which joined the labor market under different conditions of demand and supply. To account for the changes in the employment market, we include the months between graduation and August 1, 1970 as an explanatory variable.

A multivariable regression has been done to explain the period of unemployment using the following equation:

$$MU = C + a_1 MGRAD + a_2 F_1 + a_3 F_2 + a_4 F_3 + a_5 F_4 + a_6 F_5 + a_7 G_1 + a_8 G_2 + a_9 AGE \tag{4.2}$$

To analyze the effect of background and period of unemployment on earnings the following framework was used for a multivariable regression:

$$SAL = C + b_1 MU + b_2 MEM + b_3 AGE + b_4 F_1 + b_5 F_2 + b_6 F_3 + b_7 F_4 + b_8 F_5 + b_9 FS + b_{10} G_1 + b_{11} G_2 + b_{12} E_1 \tag{4.3}$$

The legend of the symbols is as follows:

F_1	= 1	if father has an education on or above post graduate level
F_2	= 1	if father has an education on or above degree level
F_3	= 1	if father has an education on or above intermediate level/diploma level
F_4	= 1	if father has an education on or above secondary level/certificate level
F_5	= 1	if father has an education on or above primary level
FS		father's present or last salary or income per month (estimated)
E_1	= 1	if employed in government service
E_2	= 1	if employed by private industry
G_1	= 1	if first division was obtained at the diploma examination
G_2	= 1	if second division or higher was obtained at the diploma examination
AGE		age at time of graduation (in years)
MU		period of unemployment after graduation (in months)
MEM		months employed after graduation
$MGRAD$	=	$MU + MEM$
SAL		Salary

The result of the statistical estimation of equation 4.2 on the period of unemployment can be summarized as follows:

- In total, 12 percent of all variance in the period of unemployment is explained by the background and ability variables considered.
- The period of unemployment has significantly increased in the last years (at the 95.5 percent level of significance).
- The period of unemployment is significantly less if the father has completed primary education or more (99 percent level of significance).
- Academic ability is only significant up to the 90 percent level of statistical significance for the first division.
- The other variables, like age at diploma examination, whether the father has an education above the primary level, father's salary, and whether the graduate received a second division or less, are not even significant on a 90 percent level.
- From the sign of the coefficients, we would deduce that the period of unemployment increases with an increasing age at the diploma examination, if the father had postgraduate training or a secondary education or more, and if the graduate obtained at the diploma examination a third or pass division. The period tends to decrease for all other variables. None of these variables is significant, however.

Background and ability variables can be related to wages as follows: In addition to the variables used to explain the period of unemployment, a set of

variables identifying the employer is also included. Three groups of employers are distinguished: government and semigovernment agencies, private industries, and others. It appears from the regression analysis that:

- The period of employment, the age at the diploma examination, and the fact whether the graduate is employed by a private industry or not are of significant (at the 99.5 percent level) influence on wages.
- Earnings are higher in private industries and increase with the period of employment.
- Graduates earn less the older they are at the time of graduation.
- On a lesser level of significance (97.5 percent), the father's salary influences his son's wages positively.
- The salary tends to be less if the father has an education on or above the primary level (significant on 97.5 percent level).
- In total, 35 percent of the variance in earnings is explained by the full set of variables.
- The signs of the other variables that are not significant on or above a level of 95 percent are mostly consistent with the influence one would expect them to have on wages.
- The period of unemployment does not have a significant impact on wages; this remains true under all possible combinations of the independent variables selected.

The last result provides an interesting view on the period of unemployment after graduation. It suggests that those who forego income when unemployed after graduation do not become less employable in the view of employers (taking wages as an indicator of employability).

A caveat in generalizing the findings of the regression analysis is necessary since all earnings data have been collected as discrete variables (split up in earnings levels). Since a discrete variable cannot be used as the dependent variable,[11] earnings have been reconverted to a continuous form by assigning the midpoint of the intervals in each case. This may lead to inaccuracies as most employed respondents appear to earn Rs. 200 or Rs. 400.

Regional Mobility

More than half of the employed respondents worked in the geographical division in which they were trained. It may then be concluded that—if the respondents' behavior in the sample is characteristic for the universe—the distribution of polytechnic training capacity is more or less in accordance with the distribution of jobs for polytechnic graduates throughout Bangladesh's geographical divisions.

To put the migration between training and employment in perspective, we also considered the migration of graduates between the place of secondary school education (often the place of permanent residence) and the place of employment. Now we find that more than two thirds of the graduates received their polytechnic training in the geographical division where they completed their earlier education.

SUMMARY

The focus of this chapter has been on the employment of graduates of educational institutes. Measurements of employment characteristics of graduates such as periods of unemployment, length of employment, starting and present salary were presented and discussed. The interrelationships between the supply of graduates, employment, wages, and the personal attributes of graduates have been worked out in one concrete setting of polytechnics in Bangladesh. But the methodology used in this analysis is generally applicable.

The analysis framework developed here will be used in the decision model in Chapter 5 that concentrates on the problems of educational resource allocation when manpower needs are met as closely as possible.

NOTES

1. See M. Blaug, P.R.G. Layard, and M. Woodhall, *The Causes of Graduate Unemployment in India* (London: Allen Lane, The Penguin Press, 1969), pp. 1-10; and K. J. Arrow and W. M. Capron, "Shortages and Salaries: The Engineer Scientist Case in the USA," in *The Economics of Education*, ed. M. Blaug (Baltimore, Maryland: Penguin, 1969).

2. Metcalf in fact shows that the gains made by shopping around for a brief period can well exceed the income foregone during that period. See D. Metcalf, "Pay Dispersion, Information and Returns to Search in a Professional Labor Market," *Review of Economic Studies*, vol. 4, no. 124 (October 1973). See also E. S. Phelps, ed., *Micro Economic Foundations of Employment and Inflation Theory* (New York: John Wiley, 1970).

3. M. Obaidullah, "A Study of Employment Survey of Graduates," Institute of Statistical Research and Training, University of Dacca, 1971 (mimeographed report).

4. Ibid.

5. Government of East Pakistan, Planning Department, *Manpower Planning in East Pakistan* (Dacca: East Pakistan Government Press, 1969).

6. Among the government and semigovernment agencies, the Agricultural Development Corporation (ADC) is known to offer the best salaries, followed by the Water and Power Development Authority (WAPDA), Irrigation Section.

7. Advertisements from *Pakistan Observer* and *Morning News*, October 1970-February 1971.

8. National Commission on Manpower and Education, *Industrial Manpower Skills* (Karachi: Government of Pakistan Press, 1969).

9. Ibid.

10. U. Kann, "Follow-up Study of Graduates from Swedish-Pakistan Institutes of Technology" (mimeographed report). Swedish International Development Authority (SIDA), 1970.

11. J. Kmenta, *Econometrics* (New York: Macmillan, 1971), pp. 425-30.

CHAPTER

5

A DECISION MODEL FOR TECHNICAL EDUCATION

ANALYSIS FOR DECISION MAKING

Let us restate the problem considered throughout this book. Any country, whether developing or developed, can ill afford to be wasteful in its resource allocations and therefore must rely on careful planning. The supply of well-educated manpower, appropriately trained and employed, helps ensure technical development. A government that seeks to make optimal decisions for technical education development must consider its education plans in the light of manpower needs. If analytical tools are available, they must be put to work.

The decision model is a tool developed to assist planners by taking into account capacity changes, curricula changes, changes in the distribution of capacity over courses (technologies) and regions. Thus, the decision model is not a behavioristic description of the process of decision making as the name might suggest. The decision model is a comprehensive structure that provides the detailed resource allocation requirements resulting from a set of policies based on some specified organization of training and employment. It is in the form of a mathematical model.

The decision model was developed in connection with a study of the polytechnics in Bangladesh. There does not seem to exist, however, any reason why the model is not applicable to the technical education sector as a whole in other places. Therefore, we shall refer to "technical education" in describing the model with the exception of those details that require a narrowing down to polytechnics.

The concept of the decision model roots mainly in the theories of systems and optimal control of systems.[1] Some similarities also exist between the concept laid out here and planning programming budgeting systems, management information systems, and techniques on decision explication, like the technique of iterative decision making (Delphi Technique).

The previous chapters that have dealt with training and employment provide the analytical base for such a "decision model." Conceptual models on the flow of students and the behavior of the employment market, such as those in Chapters 2 and 4 in this book, abstract from real life processes using a limited number of variables and thereby identify important dynamics of the system. A missing piece of the study is a macrocomparison between policies and practical achievements. This is done in the present chapter. For this comparison we are particularly interested in identifying variables that describe policy implementation. The elaboration of these studies of student flow, employment, and costs *systems* is then not too difficult.

The two models (training and employment) developed in preceding chapters can be expressed fully in quantitative terms; this quantification produces a mathematical model (a set of mathematical constraints) that can be manipulated. Alternative policies can be simulated or optimal trajectories for investments can be calculated given demand forecasts.

We must sound a note of caution here concerning the availability of information. Components of the model may be quantifiable, while data are inaccurate or unavailable in the form needed for the model. (Our attempts to measure recurring costs by technology and institute in Chapter 3 are a case in point.) To complete an integrated mathematical model of training and employment one must include demand forecasts (see section entitled "Employment Quantified: Demand Forecasts") and place the model of the employment market in its proper setting within the economy (see section entitled "A Comprehensive Decision Model," where the mathematical model is described in full).

The decision-oriented information system and the mathematical model are closely related. The information system primarily collects and processes those data required to update the mathematical model. The mathematical model is developed to be used for the analysis of the consequences of policies. Policies determine targets, constraints, and performance criteria but are generally not specified quantitatively. Policies on technical education state verbally a number of objectives on the rate of return of technical education, unemployment, geographical distribution, etc. Some of these objectives may be conflicting. Preferences have to be attached—implicitly or explicitly—in order to arrive at decisions.

The mathematical model requires that the preferences for each of the targets should be made explicit, quantitatively, as should be the targets themselves. In the section entitled "From Policy to Quantified Targets" we describe

a procedure by which the policy makers can arrive at quantitative targets and at the preferences attached to them from the verbally expressed policy.

The set of quantitatively expressed targets with their preference ratings can be considered the criterion for making optimal decisions on technical education given the physical properties of the student flow and the market behavior. Most sets of targets and preferences relate to one or more sets of decisions that best satisfy that set of targets and preferences. In a particular set of decisions, for example, we can measure the degree of satisfaction of a criterion by the deviation of the targeted from the preferred outcome; this is done mathematically by the sum of the squared deviations of each target from the actual achievement times the preference for achieving that target.[2] The set of decisions is optimal if for all feasible decisions this sum is minimal. Deviations between actual achievement and the target are squared since we want to account equally for positive and negative deviations. For some targets the decision maker only wants to penalize for negative deviations of the actual achievements from the targets. The criterion function can be adjusted accordingly.

The mathematical model enables us to define the decisions for which the the criterion function is minimized (and thus the satisfaction is maximized). This will be described further in the section on "Optimal Budget Allocations."

To summarize, the three main elements of the decision model are

1. a decision-oriented information system in which is specified (a) the information necessary with respect to the policy objectives and the systems dynamics (as set out in the mathematical model), (b) the flows of information between the institutes and the government department with jurisdiction over technical education;
2. a framework for the translation of qualitative policy objectives into quantitative targets and preferences;
3. a mathematical (simulation) model of the student flow and employment market.

Control, Exogenous, State, and Output Variables

The decision model that is created for the purpose of finding methods of "optimal control" or "best" decision making is based upon the models of training and employment. It is a "state space" approach.

The "state space" approach applied to the system of technical education divides the variables into control variables, exogenous variables, state variables, and output variables. The control variables are those that can be manipulated by the government agency that makes decisions on budgets and capacity. The variables in which the budget is expressed (recurring and nonrecurring

expenditures) are control variables; once the curricula, hiring and firing of teachers and other personnel, examinations, etc., are fixed, the aggregate level of the budget becomes the only control variable. In this model, as in the real world, actual control of the system is restricted to the purse strings once the normative structure has been determined.

There is another type of variable that influences the system of technical education. These variables, however, cannot be manipulated by the central administration or heads of schools and therefore are called exogenous variables. Social demand for training is such a variable.

The third group of variables we distinguish are the state variables. These are variables with a "memory," in the sense that their value is determined by the history of the system over a certain period preceding the present moment. Most state variables relate to supply, such as the stock of buildings of the technical schools, the stock of equipment, or the stock of graduates. The size of classes is also a state variable. The size of a nonbeginning class is determined by the size of the same year class a year before (repeaters) and the size of the previous year class a year before (promotees), while the total school capacity may be determined exogenously and the size of entering classes may be controlled through admission requirements. Thus the variables of the student flow carry some memory and can be viewed as state variables.

The quantitative targets set by the planning department are often in terms of the state variables one or more years ahead. Some targets may be related uniquely to one state variable only, others may be in terms of some combination (linear or nonlinear) of a number of the state variables. Variables that can be written as a combination of the state variables are called output variables. The use of the term "output" in "output variables" relates to informational output rather than physical output.

Training and Employment of Graduates: Summary

The model of student flows and employment markets forms the cornerstone of the decision model. In order to use the methods and results of preceding chapters, we shall summarize them here for use in the decision model; we will be careful to make distinctions between control, exogenous, state, and output variables.

Capacity for Training of Graduates

The variables determining the training capacity can be aggregated into (1) stock of investments (land, buildings, and equipment; (2) recurring

expenditures (maintenance, salaries, etc.); and (3) supply of teachers (principal, teachers, instructors, etc.) and other personnel.

The actual capacity is the minimum of the capacities created by each variable individually; for example, if there are only two teachers in a technical institute, the actual capacity is determined by the student-teacher ratios times two, however big the buildings are or however high the salaries the teachers receive (excluding double shift of teachers). In our analysis, however, we always assume that investments are the main bottlenecks and that recurring funds and teachers are exactly determined to match the capacity created by investments.

These assumptions imply that the supply of teachers is always adequate to match the demand that can be regarded as reasonable if we are only interested in *numbers* of teachers available without regard to their qualifications. In fact, in many places an acute shortage exists for teachers with industrial experience and a completed technical teacher training course. Later we shall indicate a way of projecting the need for qualified teachers once decisions on investments have been made.

Similarly, recurring funds may not be available to fill the level required of capital investments. Once we know the capacity created by the stock of capital investments, we shall project the level of recurring funds required by this capacity.

The decision to make new investments at any time can be made independently of other considerations and thus can be regarded as a control variable. The stock of capital already invested is a state variable. The projected requirements for teachers and recurring funds are output variables as they combine state variables. In our model recurring expenditures shall relate to enrollment desig nated by year classes rather than simply to total enrollment.

Flow of Students

At any time, once capacity is fixed, we can deduce the flow of students since places are first allocated to continuing students and the balance allocated for new admissions. The sizes of the continuing classes (in our Bangladesh case, second- and third-year classes) are determined by rates of promotion and repetition and can be regarded to be state variables.

Stock of Graduates

The stock of graduates is subject to attrition due to mortality and persons leaving the profession, for example, to continue studies. The stock is increased by the yearly supply of new graduates. Stock of graduates is a state variable; verbal and mathematical descriptions of the framework for studying flow of students and stock accumulation of trained graduates have been given in detail

in Chapter 2. We will discuss the employment market and demand for graduates in detail later in this chapter.

A MANAGEMENT INFORMATION SYSTEM FOR TECHNICAL EDUCATION

Since technical education in most developing countries has the objective of providing trained manpower, we can consider decision making in technical education analogous to decision making in any nonpublic system, for example, an industrial plant. The decision maker in charge of the technical education sector asks himself questions similar to those asked by the manager of an industrial plant; for example, is the product marketable? (is the graduate employable?); what should the production that yields maximal profit be, the supply and demand curves being known? (what is the output of technical education institutions that yields the maximum discounted social return of graduates resulting from investments in technical education?); what is the relation between production and the costs per product? (what is the relation between output and costs per graduate?); what is the average duration of the process of production? (how long does it take on the average to produce a graduate?); etc.

The decision maker needs a great deal of decision-based or management information to answer these questions. We shall call the complete set of such information required by each decision maker in the technical education sector a "management information system" or a "decision-based information system." The management information system can be viewed as having two components: one describes those indexes that are crucial for decision making,[3] and the second determines means for getting data to the appropriate decision maker. Both of these components require special administrative effort; neither is likely to be handled satisfactorily "by chance."

Requirements for Information

There are two kinds of information requirements for information: (1) data that reflect practice as opposed to policy objectives, for example, data that deal with the labor market for graduates from technical education institutions in sufficient detail to investigate the employability of graduates, shortages or oversupply of graduates, and to estimate rates of return; (2) data that reflect the production process of the manpower concerned, that is, data on enrollment and costs of technical education institutions.

Accounting data seldom are relevant for decision making. The purpose of accounting is to provide a check on the balance between amounts allocated and amounts spent and to describe the past rather than the future. Many of the statistics required for decision making on the costs of technical institutions have to be acquired since no other service is available; it is hoped that the requirements for decision-based statistics may induce changes in bookkeeping formats. For example, in the Bangladesh case study, the decision-based information system would require that costs of polytechnics be given in three categories: costs of the diploma courses, costs of the certificate courses, costs of the commercial courses.

We shall analyze the information requirements for decision making by considering the statistics on the capacity for training, the flow of students, the stock and employment of graduates, and statistics on the demand for graduates.

Statistics on the Capacity for Training

Capacity relates to three relevant aspects of decision making, centered around the questions: Is the capacity fully utilized? What is the relation between costs and capacity? Are capacity components optimally tuned?

Given the normative structure of the education plan, the following statistics are required annually to answer these questions and to make comparative studies on the capacity and costs between institutions. Each variable is preceded by a symbol denoting that variable.

Capital

First let us define all variables:

c_1 = Changes in the value (in constant monetary units, based on a given year) of government land in use by the technical institute as a result of acquisition or sale of land over the past academic year.

c_2 = Costs (in constant monetary units) of new construction completed in the past academic year.

$c_{3,i,j}$ = Foreign exchange component of new inventory, purchased in the past academic year (in dollars), for use by each year class and by course.

$c_{4,i,j}$ = Local currency component of new inventory purchased in the past academic year, for use by year class and by course (in local currency unit).

c_5 = New inventory used for overhead (in local currency) purchased in the past academic year.

The subscript i indicates the year class (for example, $i = 1, 2$, or 3), the subscript j indicates the course.

c_6 = Total net available floor space.

The distribution of the net floor space (that is, the gross floor space minus space for halls, corridors, and stairways) over courses and year classes is required in order to distribute the costs of the buildings over the users. We therefore introduce further variables that relate to space:

$c_{7,i,j}$ = Surface of classrooms and laboratories by course by year class.

$c_{8,i,j}$ = Surface of floor space shared by all programs.

The total number of statistics on capital costs required thus is

4(variables) + [4(variables) X 3 (year classes) X number of courses].

These statistics allow for a computation of the imputed per annum costs of running the institution generated by capital requirements.

The imputed per annum costs of the land is the imputed rent of the land (the commercial interest rate per annum times the present value of the land). The imputed per annum costs of the buildings is the summation of imputed per annum rents over all vintages of buildings. Since buildings depreciate and have to be replaced, the calculation of imputed rents for buildings (and also for inventory) differs from the one for land. The nature of the calculation, however, is the same. The technique of imputing rent was developed in Chapter 3 and is summarized by equation 3.2.

From this overall imputed rent we can then find the imputed rent of land and buildings by each year class and course according to the share of floor space used and the per pupil share of overhead floor space. Imputed rent of inventory (local currency and foreign exchange) can be calculated in the same manner as imputed rent of buildings.

The total imputed rent for land and buildings is considered to be "charged" to year classes and courses separately. The "charge" of the total rent is based on the relative usage of course j and class i of the total buildings, measured in floor space.

The total imputed annual rent for capital used by an institute by year class i and course j thus is:

[(classroom and laboratory space of i,j)/total net floor space
+ (number of students in i,j/total number of students) X overhead floor space]
X total imputed rent for land and buildings
+ rent of inventory acquired through foreign exchange for i,j
+ imputed rent for inventory in local currency for i,j
+ (number of students in i,j/total number of students X imputed rent on overhead inventory

Since the normative educational plan of the institute contains standards on average floor space and inventory per student, these standards and the actual values of floor space and inventory determine the capacity as made up by capital.

Recurring Costs

The variables for the calculation of recurring costs are as follows:

r_1 = Salaries of teachers and instructors
r_2 = Salaries of overhead staff and personnel
r_3 = Maintenance and repair costs of existing facilities
$r_{4,i,j}$ = Instructional materials and supplies per course per year
r_5 = Other recurring costs.

The data on recurring costs can be broken down to recurring costs per course per year class (insofar as they are not already given in that way). Salaries of overhead staff, of maintenance and repair, and other recurring costs can be broken down on a per pupil basis by assuming equal shares used by each pupil. The teachers' salaries can be broken down to costs per course per year class on the assumption that distribution of teacher costs of courses and year classes is the same as the distribution of teaching hours over courses and year classes. The costs of teachers' salaries by course equal (total hours of class i, course j per year)/total class hours per year $\times$ total teachers' salaries.

Teachers

$t_{1,i,j}$ = Number of theory teachers and practice instructors (by course and year class, if possible).
t_2 = Number of overhead staff above matriculation level (including principal and vice-principal).
t_3 = Number of other personnel.

If qualifications of teachers are of importance, an extra set of variables describing training and experience, related to their assignments, should be added.

Statistics on the Flow of Students

There is generally little scope for control of the student flow in technical institutions once students have been admitted. It is almost universally true for

educational institutions that promotion rates, repetition rates, and dropout rates change very little (and certainly only slowly) by pressures from the administration of the institute. Occasionally, measures like the expansion or reduction of available scholarships on a large scale or the introduction of quotas after the first year are adopted. But generally, by regulating quality and quantity of the new entrants in the technical institutions through the admission examination, the administration has regulated de facto the student flow.

To describe quantitatively the flow of students, statistics are required on enrollment, dropout, repetition, and promotion. Enrollment is not constant during an academic year as dropout can occur at any point. But we shall define the enrollment in a year class of a certain course in an academic year as the number of students in that class and course at the start of the academic year. This definition ignores late entrants, which are rare, and dropouts and therefore provides a maximum enrollment figure. This definition of enrollment has been chosen with respect to resource allocation since the decision maker has to allocate most resources (space and teachers) for a class according to the maximum number of students expected at any time in that class.

In Chapter 2 we discussed in detail a number of measures of student flow. To avoid unnecessary costs of collecting and keeping enrollment data, we shall now simplify (by neglecting transfers between schools) the characteristics of the student flow by defining *promotees* to be the number of students promoted from a year class and actually entering the following year class (taken at the start of a year class), *repeaters* to be the number of students repeating a year class, taken at the start of an academic year. The data on enrollment, repetition, and promotion thus all relate to the same date. Dropout is then defined by the difference between the enrollment in a year class i in year t and the sum of the numbers of promotees in year class $i+1$ and the number of repeaters in year class i in year $t+1$.

The promotion, repetition, and dropout rates are

$$\frac{\text{promotees}}{\text{enrollment}}, \frac{\text{repeaters}}{\text{enrollment}}, \text{and } \frac{\text{dropouts}}{\text{enrollment}}.$$

The three rates add to unity as can be seen from the definitions.

These definitions relate to the quantity of the student flow. Insight into the qualitative aspects of the student flow requires a breakdown of the enrollment statistics into separate categories of academic qualification. If this is of importance and interest, separate student flow rates can be studied for these different groups.

Summarizing, we propose to collect at the beginning of each academic year

$e_{1,i,j}$ to $e_{4,i,j}$ = the number of promotees in each year class in each course for each of the four quality groups,

$e_{5,i,j}$ to $e_{8,i,j}$ = the number of repeaters in each year class in each course for each of the four quality groups.

Since our purpose is to make use of student flow data for decision making on resource allocation, the definition of output of a year should be based on the claims on resources made by that output. The corresponding definition is: the output of an academic year t to $t+1$ is the number of diplomas awarded to students who followed the third-year class in that academic year t to $t+1$. This definition recognizes that the output is formed by the diplomas awarded at the regular examination of that year plus the diplomas awarded at the first following supplementary examination. The graduation rate is then defined as:

$$\frac{\text{Output}}{\text{Enrollment}} \text{ of a certain course in a certain year.}$$

So additionally we propose to collect

$e_{9,j}$ = the number of graduates stemming from the enrollment in the third-year class in each course for each of the four quality groups, divided by the grades received at the final examination (first or second class or passed). The total number of statistics annually to be collected is *per course:*

$$[2\,(\text{variables}) \times 3\,(\text{year class}) + 1\,(\text{output})] \times 4\,(\text{quality groups}) = 28$$

Statistics on the Stock and Employment of Graduates of Technical Institutions

In Chapter 2 we looked at stocks of graduates and in Chapter 4 at the employment market for graduates. In order to do effective planning, decision makers must have accurate and continuing data on both the supply of and demand for graduates of their institutions and must be able to answer questions such as: Have the technical institutions oversupplied or undersupplied (regionally and nationally)? What is the private and the social rate of return to education (given the data on costs from the section on "Statistics on the Capacity for Training")?

Such questions can be answered if information is collected on a continuing basis on the careers of a random sample of the graduates. Records should be updated annually and kept strictly confidential. The basic information on the record should be as follows:

General
- Name
- Father's educational qualification
- Father's occupation

Academic Record
- District, year, subjects studies, grades at last examination
- Other academic examinations (if any)
- Other professional qualifications

Employment Record
- Period between the awarding of the diploma and employment.
- Year of start, district, salary of start, employer, and occupation of first employment
- Annual employment status, registering for each job (if more jobs are held at a time or in the year): employer, district, salary, occupation of employment, hours and weeks worked.

The employment records would provide time series on a number of variables (most important, the salary) of a fixed, randomly selected group of graduates. Since the same people would be questioned annually, these data would truly constitute a longitudinal sample on salaries, employers, places of employment, and occupations. Such data are called panel data and are preferred for statistical evaluation over time series of cross-sectional data which consist of information collected by taking a new random sample of the population each year.

Employment records provide the data to identify and compare over time by course and by institute where trained: absolute values and changes in the period of unemployment, categories of employers (government and semigovernment, nonmanufacturing, public industries, private industries, and other employers), salaries, and expected life income streams.

Employment records of graduates neglect two aspects of the job market that are important for evaluation:

1. the degree to which graduates are hired for the occupations for which they are trained. To do this, occupation-employment information should also be collected, that is, data on persons who occupy jobs for which technical school graduates are trained: Are most jobs in these occupations filled by graduates of technical institutes? What are the qualifications of the non-graduates who are employed? Occupation-employment information can only be collected directly from employers, once occupations are comprehensively defined.

2. the employment of dropouts of the technical schools. As mentioned before, students drop out for other reasons than ability. A sample survey, such as the one described above, can be used to follow dropouts.

Statistics on the Demand for Graduates of Technical Institutes

Manpower forecasts—that is, projections of future demands for technical school graduates—are required for proper analyses and decisions on training capacity. One such example is the report: *Manpower Planning in East Pakistan* of the manpower section of the then Government of East Pakistan (Dacca, 1969). In this report, manpower forecasting is based upon (1) time series of the number of technical school graduates employed in different salary scales, and (2) total investments and output in the private and public sectors (by sector).

Flows of Information

It may seem too obvious to be worth mentioning, but if information is to be useful for decision making, it must be requested by the decision makers. Nevertheless, it is too often true that information is collected that is of very little value, while vitally needed data such as employment statistics are ignored. The flows of information we propose here have been designed to follow the criterion that information channeled to a decision making unit is a prerequisite for a rational decision-making process.

Let us consider the case of planning in Bangladesh. The need for information for decision making at the level of the Directorate of Technical Education (DTE) is clear as the DTE is "responsible for the development and control of Technical Education,"[4] and is in charge of the budget. The need for information of the individual polytechnics is less clear since the power for decision making at an individual polytechnic is not too clear in this macro context.

Two separate decision-making units now have been identified regarding this flow of information: the individual polytechnics and the DTE. The DTE resides formally under the Ministry of Education, which has the ultimate decision power. For our purposes, we can introduce the simplification that only the ministry decides on the distribution of the total education budget over the subsectors and thus fixes the ceiling for expenditures in the technical education sector. It is then up to the DTE to decide how to allocate the budget to polytechnics, vocational training institutes, etc. This description is a simplification since the distribution of the total education budget is the result of an iterative interaction process between the subsectors and various government departments. All subsectors of the education system submit tentative budgets to the Ministry of Education, which adapts these budgets to its own priorities and negotiates with the Ministry of Finance for the total amount to be allocated for the education sector. In case of capital expenditures, the Ministry of

Planning has to give its fiat before the Ministry of Finance can consider the project. The decision model assumes that the total budget allocation is known and that therefore the problem is reduced to how to allocate the total budget optimally, among courses. In Bangladesh, most of the information mentioned in the section on "Requirements for Information" as decision oriented is being collected in one way or another, but retrieval and processing of the raw information must be done to make it accessible for decision making.[5]

FROM POLICY TO QUANTIFIED TARGETS

Policy and Implementation

The planning of technical education should lead to the formation of a detailed budget for a future period. Such a budget should contain details of both recurring and capital expenses per institute, per technology offered, per year.

This expenditure serves a number of targets that are implicitly included in "the education policy." The planning process should attempt to translate the theoretical policy as faithfully as possible into practical action. The principal difficulties encountered in this process are that "the policy" is mostly in general terms, it is expressed verbally (not quantitatively), and it may contain largely contradictory goals that have to be reconciled in a good implementation program. It is important here to describe more extensively what we mean by policy and implementation.

In Bangladesh, for example, basic elements of "the policy" on technical education occurred in: Six-Year Educational Development Plan (1951); First Five-Year Plan (1955-60); Report of the Commission on National Education (1959); Second, Third and Fourth Five-Year Plans (1960-65, 1965-70, 1970-75); New Educational Policy (1970). The documents state general policy targets. These statements are the input of the planning process, and the forms describing a development (capital investment) project are the output. The forms are supposed to cover the whole spectrum of the policy—the related targets and the resulting capital budget for a distinct project (like the expansion of a polytechnic).

Policy Consideration

Let us look at the case of Bangladesh for an example of how general governmental policy is translated into specific planning. We find, in official government

plans, explicit references to the primary goal of technical education, the provision of trained manpower. In the First Five-Year Plan (1955-60),

> priority will be given to . . . rapidly expanding education and training in the technical, vocational and professional fields to provide essential qualified personnel for all sectors of the development programme. . . . (p. 17)

While more specifically for vocational education and training a later section adds:

> This section deals with a relatively narrow subject: the preparation of skilled personnel for industrial and business occupations which do not require professional education at the colleges or universities. (p. 553)

Further it is recommended that

> In order to produce supervisory personnel for industry, polytechnics should be established as early as possible. (p. 554)

The Second, Third, and Fourth Plans mention the same policy toward technical education. The Fourth Five-Year Plan, however, proposes to change the normative structure of the education plan of polytechnics in order to train polytechnic graduates in scientific management techniques rather than simply for jobs as foremen and overseers. Although no specific policy for technical education emerges, the New Educational Policy (1970) states:

> Pakistan's goals of national development clearly warrant a much higher priority to be assigned to science and technical education than has been done in the past. (p. 11)

This implies that technical education—as well as general education—should contribute to "national development."

Government policy thus states that the principal task of technical education is to supply trained manpower according to the demand. The total demand for technicians on the overseer and foreman level should be met by the trainees of the polytechnics. Additionally a regional aspect is introduced. Each polytechnic is to be equipped with the training capacity exactly proportional to the demand for trained foremen, etc., of the region in which the polytechnic is situated with some allowance for a discrepancy between supply and demand. Two policy considerations permit adaptation between supply and demand to differ from one region to another, that is, (1) an oversupply of trained technicians in

a region that may induce establishment of industries in that region and thus may create "demand," and (2) polytechnic training capacity that may be partly allocated over the country to equalize opportunities regionally.

Thus, subpolicies at the regional level can be quantified as follows: we translate the national policy (manpower supply) to state the absolute targets for the polytechnics (the demand anticipated) while the subpolicies express the weight attached to meet the demand in the region in which the polytechnic is located. The degree to which supply exceeds demand can be measured by a single variable: the combined underemployment and unemployment rate or the ratio of the sum of the unemployed and underemployed graduates over the total number for a year cohort (separate for each region and each technology).

The operational definition of underemployment or employment below the level of training to be used is: employment with a salary below that of the minimum of the scale on which graduates are employed in general (this scale is to be expressed in the fixed prices of a given year) as measured by average per scale. Usual usage of the term underemployment implies that the employee is not using all skills for which he has been trained. Our definition is an attempt to measure such underemployment by simply looking at wages, rather than analyzing the job held by the graduate.

Now we can turn to the framework for the allocation of resources under budget constraints using the combined unemployment and underemployment to express the policy targets.

Policy Targets and Budget Allocations

Determination of maximum targets of the regionally oriented policy is a first step that expresses goals without regard to budget constraints. Maximum targets do not necessarily require exact matching of supply and demand, as a strict manpower-oriented policy would, since regional subpolicies do allow for an oversupply. They thus state that for each region distinguished in the planning process, demand should at least be met, with some oversupply allowed. The DTE must decide for each region exactly how much oversupply should be allowed in terms of maximum unemployment and underemployment rates. Then, given these rates, using the flow model and the manpower forecasts, the required budget can be calculated. This will be done in the section entitled "Optimal Budget Allocations." Similarly, the budget required to maintain an exact matching of supply and demand can be computed. If the total budget available is between the maximum and that required to attain zero unemployment and underemployment in all regions, an allocation problem emerges. In order to choose among alternatives, the DTE must attach preferences for

attaining the maximum rate in each of the divisions (to be indicated by a figure in a scale, say, from 0-10). The preferences allow for calculation of the optimal budget. The set of maximum targets and preferences is called the target matrix.

Let us clarify this with the following example of how the DTE determines the target matrix: The maximum under- and unemployment rates are 0.05, 0.07, 0.05, 0.10 for regions 1, 2, 3, and 4 respectively. The total capital budget required to attain the rates exactly is Rs. 1.78 million (the maximum budget). The capital budget required to attain zero unemployment and underemployment rates in all regions is Rs. 1.4 million. To determine the allocation of a capital budget of Rs. 1.64 million preferences 3, 3, 5, 5 are attached for attaining the maximum rates. If optimality is defined by a criterion expressed in quadratic form to permit both positive and negative deviations, then the allocation problem is based on the following calculation: minimize the squared deviations of the actual unemployment and underemployment rate from the normative rate, multiplied by ("weighted with") the preference summed over all regions. In symbolic form we want to minimize:

$$3(un_1 - .05)^2 + 3(un_2 - .07)^2 + 5(un_3 - .05)^2 + 5(un_4 - .10)^2 \qquad (5.1)$$

where un_i is the actual unemployment and underemployment rate of region i $(i = 1, 2, 3, 4)$ while the sum of the regional budget requirements does not exceed the total budget allocated by the Ministry of Education or

$$\sum_{i=1}^{4} b_i \leqslant Rs.\ 1.64\ million \qquad (5.2)$$

where b_i is the capital budget of division i $(i = 1, 2, 3, 4)$. This can be formalized as follows:

Minimize

$$\sum_{i=1}^{4} pr_i(un_i - \bar{un}_i)^2 \qquad (5.3)$$

where

$\bar{un}_i$ is the target unemployment rate, in region i

un_i is the actual unemployment rate in region i

pr_i is the preference for attaining the target in region i

while

$$\sum_{i=1}^{4} b_i \leqslant \bar{U} \qquad (5.4)$$

where

$\bar{U}$ denotes the available budget.

In this section we have discussed only allocations by region. It would be equally important to determine allocation by region and technology. This distinction could be introduced without difficulty.

EMPLOYMENT QUANTIFIED: DEMAND FORECASTS

The demand for graduates of a technical institute is considered to be an exogenous variable for the system of technical education, that is, no actions within the technical education system can influence the level of demand. Here we understand "demand" to be demand within a certain fixed salary schedule. Demand for graduates over a future period is the single most important determinant for decisions on the capacity of technical education under the present policy of manpower supply. Every decision on a change in capacity reflects assumptions on the demand for manpower that can be based on intuitive guesses or on analytical calculations. For a complex system like the demand for manpower, an analytical calculation should be at least as good as an intuitive guess. Quantitative projections are at least explicit, can be compared to what actually happens, and thus allow for the improvement of the forecasting methods. Intuitive guesses remain generally indefinite and are of little help for future planning.

The analytical manpower projections of the manpower planning group of the then East Pakistan Planning Department of Bangladesh are significant in this respect. The Planning Department has given predictions of the demand for polytechnic graduates in 1970 and 1975 as listed in Table 5.1. Several reasons explain the great differences in demand shown here—the chief reason being the forecast method used. The estimates are derived from the projections of the demand for university-trained engineers, assuming a ratio of 5:1 for civil engineers and of 3:1 for all other engineers in all three alternatives, and thus if the forecasts for graduate engineers are incorrect, errors in forecasts for polytechnic graduates will be magnified.

Alternative I uses these ratios in a fairly simple relationship while alternatives II and III involve a voluminous amount of information and a number of analytical steps; it is then difficult to find out the relative influence of each step on the predictions for graduate engineers. In our opinion, manpower planning must be a revolving exercise with planning models being constantly updated and improved.

This is not the place to dwell at length on various techniques used in labor demand forecasting. Interested readers are referred to the works of Ahamed and Blaug, Jallade, Bartholomew and Morris, and Parnes for details of manpower planning.[6]

TABLE 5.1

Demand for Polytechnic Graduates in 1970 and 1975

	1970			1975		
	Alternative I[a]	Alternative II[b]	Alternative III[b]	Alternative I	Alternative II	Alternative III
Civil	5,000	5,000	3,650	6,000	11,000	5,600
Mechanical	1,650	1,285	1,200	3,600	3,000	2,400
Power, radio, and electronics	2,250	1,530	1,050	3,600	3,300	1,000
Chemical	600	745	600	1,200	1,875	1,050
Total	9,500	8,560	6,500	14,400	19,775	10,850

[a]Total number of graduate engineers predicted is the weighted average of the number of engineers forecasted on the basis of a linear relation between investment and graduate engineers and the number of engineers predicted on the basis of a linear relation between output and graduate engineers.

[b]Total sectoral employment is computed from total output on the basis of logarithmic relations between employment and output, sectoral employment is broken down into employment by occupation; employment by occupation is translated into employment by education.

Source *Manpower Planning in East Pakistan*, Planning Department, Government of East Pakistan (Dacca: East Pakistan Government Press, 1969), Table 2-V-1, p. 44; Table 2-V-2, p. 47; Table 2-V-3, p. 50.

A COMPREHENSIVE DECISION MODEL

The Mathematical Model

The three cornerstones of the decision model have been identified to be (1) the decision oriented information system, (2) the policy quantification framework, and (3) the mathematical model of training and employment. The mathematical model has been developed in bits and pieces before: the student flow and manpower accumulation have been described in Chapter 2, the relationships between training capacity and costs in Chapter 3, the assumptions on the employment market were explored earlier in Chapter 4, and demand forecasting has been discussed in this chapter. Now these pieces will be brought together.

In constructing the model the distinction between control, state, exogenous, and output variables as previously outlined will be maintained. Control variables are denoted by u, state variables by x, output variables by y, and exogenous variables by z.

Presented below is the mathematical formulation matching the verbal description for the capacity training of technicians of a particular specialty in an educational institute with a three-year maximum.

1. The creation of training capacity:

$$x_{t+1,1} = (1 - \delta)x_{t,1} + u_t \tag{5.5}$$

where

u_t denotes new investments in year t (a control variable)

$x_{t,1}$ denotes the total depreciated investment in training capacity in year t (a state variable)

δ represents the annual depreciation rate (a technical coefficient).

The allocation of new investments is assumed to be subject to the natural constraint:

$$u_t \geqslant 0 \tag{5.6}$$

This constraint says that training capacity cannot be sold out.

2. Enrollment in first-year class: The enrollment capacity in the first-year class is an output variable:

$$y_{t,1} = lx_{t,1} - \sum_{j=2}^{3} x_{t,j} \tag{5.7}$$

where

y_t = number of students enrolled in the first-year class
l = the reciprocal of the investments per student such that the product $lx_{t,1}$ indicates the total number of student places
$x_{t,j}$ = number of students enrolled in year t in the second-year class (if $j = 2$) or the third (if $j = 3$). Both are state variables.

We have chosen "new investment" to be the control variable; as a result the total training capacity is determined. If we assume that promotees from the first- and second-year classes have a priority in allocating the places available, then the size of the first-year class is strictly determined by whatever is left over, as is formalized in equation 5.7.

3. Enrollments in second- and third-year classes and stock of graduates. The sizes of the second-and third-year classes are determined by promotion and repetition:

$$x_{t+1,2} = a_{21}y_{t,1} + a_{22}x_{t,2} \tag{5.8}$$

or using equation 5.7:

$$x_{t+1,2} = a_{21}(lx_{t,1} - x_{t,2} - x_{t,3}) + a_{22}x_{t,2} \tag{5.9}$$

and

$$x_{t+1,3} = a_{32}x_{t,2} + a_{33}x_{t,3} \tag{5.10}$$

Here $a_{m+1,m}$ is the promotion coefficient from year class m to year class $m+1$; and $a_{m,m}$ is the repetition coefficient in year class m. The stock of graduates is determined by:

$$x_{t+1,4} = (1 - \zeta)x_{t,4} + a_{43}x_{t,3} \tag{5.11}$$

In equation 5.11, the stock of graduates in year $t+1$ ($x_{t+1,4}$) equals the stock of the same graduates from the previous year with allowance for attrition, and augmented by graduates from year t; the attrition rate is denoted by ζ and assumed to be equal for all years.

4. Recurring costs. The education plan under which capacity decisions are made specifies certain standards such as student-teacher ratios and library and laboratory needs per student, which then are translated into recurring costs per student. Recurring costs and teacher needs are found from the required recurring costs per student and the student-teacher ratio with the number of students as given by capacity decisions. They thus are output variables.

The total recurring costs of a course of a polytechnic then amount to:

$$y_{t,2} = \mu_1 y_{t,1} + \mu_2 x_{t,2} + \mu_3 x_{t,3} \tag{5.12}$$

or with equation 5.7:

$$y_{t,2} = \mu_1 l x_{t,1} + (\mu_2 - \mu_1)x_{t,2} + (\mu_3 - \mu_1)x_{t,3} \tag{5.13}$$

where $y_{t,2}$ indicates total recurring costs needs in year t, and μ_j denotes the recurring costs per student in year class j.

Thus equation 5.8 says that total recurring costs in a particular year equal the sum of the recurring costs for the three-year classes in that year.

The output variables, denoted by y, take on differing forms, for example, y_1 indicates students, y_2 indicates recurring cost, y_3 indicates teachers, and y_4 indicates the stock of unemployed graduates.

5. Teachers. The staff requirements are projected to be

$$y_{t,3} = \gamma_1 y_{t,1} + \gamma_2 x_{t,2} + \gamma_3 + \gamma_3 x_{t,3} \tag{5.14}$$

or after substitution of equation 5.7

$$y_{t,3} = \gamma_1 l x_{t,1} + (\gamma_2 - \gamma_1)x_{t,2} + (\gamma_3 - \gamma_1)x_{t,3} \tag{5.15}$$

where $y_{t,3}$ stands for the total number of teachers required in year t and γ_j denotes the teacher-student ratio in year class j.

6. Demand for graduates. Forecasts of the demand for employment have been discussed previously. Demand for graduates in a year t is exogenously determined and is denoted by z_t. Over and under supply is defined by the difference between supply (the stock) and demand and is denoted here by $y_{t,4}$:

$$y_{t,4} = x_{t,4} - z_t \tag{5.16}$$

The combined unemployment and underemployment rate denoted by un_t equals

$$un_t = \frac{y_{t,4}}{x_{t,4}} = 1 - \frac{z_t}{x_{t,4}} \tag{5.17}$$

Summarizing items 1 through 6 and rewriting the equations in vector form, we recognize a system of difference equations denoting student flow and stock accumulation:

$$\underline{x}_{t+1} = A\underline{x}_t + \underline{b}u_t \tag{5.18}$$

where $\underline{x}_t$ is a vector with elements $x_{t,j}$ $(j = 1,2,3,4)$ and A is the four by four matrix:

$$A = \begin{bmatrix} (1-\delta) & 0 & 0 & 0 \\ a_{21}l & (a_{22}-a_{21}) & -a_{21} & 0 \\ 0 & a_{32} & a_{33} & 0 \\ 0 & 0 & a_{43} & (1-\zeta) \end{bmatrix} \tag{5.19}$$

The first and only nonzero element of vector $\underline{b}$ is 1. Then from equations 5.7, 5.13, 5.15, and 5.16 we can express output as a linear combination of the state and the exogenous variable:

$$\underline{y}_t = C\underline{x}_t + \underline{d}z_t \tag{5.20}$$

where $\underline{y}_t$ is a vector with elements $y_{t,j}$ $(j = 1,2,3,4)$ and C is a four by four matrix:

$$C = \begin{bmatrix} l & -l & -l & 0 \\ \mu_1 l & (\mu_2-\mu_1) & (\mu_3-\mu_1) & 0 \\ \gamma_1 l & (\gamma_2-\gamma_1) & (\gamma_3-\gamma_1) & 0 \\ 0 & 0 & 0 & l \end{bmatrix} \tag{5.21}$$

$\underline{d}$ is a column vector: $\underline{d} = \{0, 0, 0, -l\}$

The information system is vital for the updating of the mathematical model. All coefficients have been assumed to be constant over time. Of course, they are actually only constant in exceptional cases (for example, if a coefficient is normatively determined). Most coefficients are, however, not time *dependent* either; or if they are, we do not know what the relationships between the coefficients and time dependent variables are. The coefficients *vary* over time. The time-varying aspect of the coefficients can be incorporated better in a model by updating the model rather than assuming time trends for the variation of the coefficients over time.

In one aspect the model described above is different from the treatment of the previous sections: real investments are used here instead of rental values. The decision maker nevertheless will be required to think in rental values as well as in real investments in order to judge the annual costs incurred in allocating these real investments.

For the interpretation of the investment cost per student and recurring costs per student variables, the following should be borne in mind: New investments

are aggregated into one single decision variable. In practice the new investments are composed of a mix of investments in land, classroom, laboratory, and overhead space, foreign exchange, local currency, and overhead inventory. The relations between the elements of the capacity are supposed to be known and rigid. Total investment then can be broken down into its constituent elements, but need not be the same for all courses and for all polytechnics. For example, the rental of an acre of land may be more costly in one region than in another, while the foreign exchange in inventory costs per unit may be the same over the whole country. A consequence is that the same amount of money may not create the same number of student places in different regions. Similarly, total recurring costs are composed of the recurring costs of different categories (maintenance, classroom and instruction material, etc.). From the total recurring costs the individual cost categories can be calculated.

Optimal Budgeting

Budgeting is called optimal if the budget distribution reflects as closely as possible, under given constraints, a given policy. Constraints can appear in the form of a budget limit—if expansion is required—or in the form of the existing training capacity when manpower goals dictate a sharp decrease of capacity. Optimal budget allocations are then derived with the mathematical model. To do that the policy has to be expressed in quantitative terms (see the section on "From Policy to Quantified Targets").

No time period has as yet been specified for the planning process, indicating that the model described can be applied equally to short-term (one year), medium-term (five years), and long-term (ten to twenty years) planning of budget allocations.

The model to be used for an optimal budget control has been described in this and the preceding section. The objective function can be expressed as follows:

$$\text{Minimize} \sum_{t=4}^{T+4} pr_t (un_t - \overline{un}_t)^2 \qquad (5.22)$$

where $t = 0$ denotes the initial year of the planning period

T denotes the final year of the planning period

$\overline{un}_t$ is the normative value or maximum target for the year t

un_t is the actual value of unemployment for year t

pr_t is the preference for attaining the maximum target in year t; or, rewriting equation 5.22 using the relationship between demand and supply of equation 5.17:

$$\text{Minimize} \sum_{t=4}^{T+4} pr_t \left\{ 1 - \frac{z_t}{x_{t,4}} - \overline{un}_t \right\}^2 \tag{5.23}$$

$$\underline{x}_{t+1} = A\underline{x}_t + \underline{b}u_t \tag{5.24}$$

while selling capacity off is prohibited:

$$u_t \geqslant 0 \tag{5.25}$$

with the initial value of the $\underline{x}$ vector given by $\underline{x}_0$, so that

$$\underline{x}_{t=0} = \underline{x}_0 \tag{5.26}$$

In addition, budget constraints can arise, so that

$$\sum_{t=0}^{T} u_t \leqslant \overline{U} \tag{5.27}$$

and $\overline{U}$ is the maximum budget available over the planning period.

The period for summation in the objective function runs from $t = 4$ to $t = T+4$. This is necessary since new investments do not create output (of new graduates) until four years later. As a result the effects of the investment during the planning period are to be found in the output of graduates four years later.

OPTIMAL BUDGET ALLOCATIONS

Under different circumstances of budget constraints, the path of demand for graduates, and the length of the time period, the problem of finding the optimal investment trajectory can be solved by relatively simple means. Such solutions will be explored in this section. If for a longer-term planning period, (a) the budget constraint is binding, that is, if the budget requirements to satisfy manpower needs exactly are above the actual budget available, or (b) the demand trajectory fluctuates "considerably" over time, or (a) and (b) appear simultaneously, then the problem of finding the optimal budget allocations most often requires more sophisticated mathematical techniques, like quadratic programming,[7] explored in the following section.

For the present, we will consider situations under which optimal budget allocations can be obtained. Such circumstances are (1) the planning period is one year only; (2) the budget constraint is not binding and the demand trajectory is smooth enough as not to force the selling off of training capacity; these

are called simplifying assumptions in the calculation of the optimal investments. If it follows from the optimal solution that, in fact, at some point in time training capacity has to be sold off, but that the budget constraint is not binding, then the solution can be found with simpler means than quadratic programming.

One-Year Optimal Budgeting

A slight difference occurs in the use of the model for the short-term, on the one hand, and medium- and long-term planning, on the other hand.[8] The one-year budget allocation problem is clearly based on achieving the maximum targets (weighted with the preferences) at the end of the year on which the new investment has an impact. Longer-period allocation problems, however, are concerned with minimizing the sum of the annual squared differences of the actual unemployment and underemployment rates from the maximum targets, weighted with the preferences, over the total planning period, rather than minimizing the squared differences of the rates from the maximum targets in each year of the planning period. The one-year planning process aims at minimizing a single squared deviation, the longer planning process aims at minimizing a sum of squared deviations which may not be the same as minimizing each squared deviation separately.

If the problem is restricted to finding that value of investments in year $t=0$ which minimize the deviation between actual and target unemployment rates,

$$un_{t=4} = \overline{un}_{t=4} \tag{5.28}$$

or with equation 5.17:

$$1 - \frac{z_{t=4}}{\bar{x}_{t=4,4}} = \overline{un}_{t=4} \tag{5.29}$$

such that

$$\bar{x}_{t=4,4} = \frac{z_{t=4}}{(1-\overline{un}_{t=4})} \ . \tag{5.30}$$

If the target supplies of graduates are known in year $t=4$, the budget allocation required to match these stock sizes $(\bar{u}_t)$ can be traced back as follows:
Third-year enrollment in year $t=3$, using equation 5.10:

$$\bar{x}_{t=3,3} = \frac{1}{a_{43}}\bar{x}_{t=4,4} - \frac{1}{a_{43}}(1-\zeta)\bar{x}_{t=3,4} \tag{5.31}$$

Second-year enrollment in year $t=2$, using equation 5.9:

$$\bar{x}_{t=2,2} = \frac{1}{a_{32}} \bar{x}_{t=3,3} - \frac{a_{33}}{a_{32}} \bar{x}_{t=2,3} \tag{5.32}$$

Total training capacity in year $t = 1$:

$$\bar{x}_{t=1,1} = \frac{1}{a_{21}l} \bar{x}_{t=2,2} - \frac{a_{22} - a_{21}}{a_{21}l} \bar{x}_{t=1,2} + \frac{l}{l} \bar{x}_{t=1,3} \cdot \tag{5.33}$$

With equation 5.5, we find then:

$$\bar{u}_{t=0} = \bar{x}_{t=1,1} - (1 - \delta)\bar{x}_{t=0,1} \cdot \tag{5.34}$$

The variables used at the right-hand sides are—with an exception of the stock of graduates in year $t = 4$—determined by the enrollments and the accumulated investments in training capacity in year $t = 0$. Thus they are known at the time the decision on new investments, $u_{t=0}$, has to be made.

Optimal Budgeting under Simplified Conditions for More than One Year

Investments tend to follow a smoothly increasing trajectory, and sudden and large changes in the sectoral demand for graduates need not be expected. If indeed the assumption of smoothness holds, if the supply satisfies the demand at the initial time, and if no budget constraints are imposed, or if the budget constraint is not binding, then the minimization of the sum is the same as the minimization of the squared deviations for each of the years. Under such circumstances, the same recursive procedure of calculating the optimal values of new investments, u_t, can be used as in the previous section.

Let us examine how this is done. Consider a five-year planning period (from $t = 0$ to $t = 5$). Suppose the series of demand forecasts is given. Hence the target supplies of graduates (denoted by $\bar{x}_{t,4}$) over the period $t = 4$ to $t = 9$ are known (calculated in equations 5.28 through 5.30). An optimal budget allocation aims at matching these target supplies as closely as possible with an actual supply.

Let us assume that the target supplies ($\bar{x}_{t,3}$) and the actual supplies match exactly. The recursive equations developed in the previous section can be applied to calculate the budget allocations required. Enrollment in the third-year class is determined by the following set of equations (see also equation 5.31) for the period $t = 3$ to $t = 8$:

$$
\begin{aligned}
x_{8,3} &= \frac{1}{a_{43}}\bar{x}_{9,4} - \frac{(1-\zeta)}{a_{43}}\bar{x}_{8,4} \\
x_{7,3} &= \frac{1}{a_{43}}\bar{x}_{8,4} - \frac{(1-\zeta)}{a_{43}}\bar{x}_{7,4} \\
&\vdots \\
x_{3,3} &= \frac{1}{a_{43}}\bar{x}_{4,4} - \frac{(1-\zeta)}{a_{43}}\bar{x}_{3,4}
\end{aligned}
\tag{5.35}
$$

In the last equation the symbol $\bar{x}_{3,4}$ now stands for the stock of graduates in year $t = 3$ resulting from the initial conditions. Similarly, enrollment in year class two can be calculated (compared with equation 5.32) for the years $t = 2$ to $t = 7$:

$$
\begin{aligned}
x_{7,2} &= \frac{1}{a_{32}}x_{7,3} - \frac{a_{33}}{a_{32}}x_{7,3} \\
&\vdots \\
x_{2,2} &= \frac{1}{a_{32}}x_{3,3} - \frac{a_{33}}{a_{32}}x_{2,3}
\end{aligned}
\tag{5.36}
$$

The series of enrollments in the third-year class $(x_{t,3})$ have been calculated before except for the enrollment in the third-year class in year $t = 2$, which is determined by the initial conditions.

The total training capacity can be computed in accordance with equation 5.33 to be for years $t = 1$ to $t = 6$:

$$
\begin{aligned}
x_{6,1} &= \frac{1}{la_{21}}x_{7,2} + \frac{a_{21}-a_{22}}{la_{21}}x_{6,2} + \frac{1}{l}x_{6,3} \\
&\vdots \\
x_{1,1} &= \frac{1}{la_{21}}x_{2,2} + \frac{a_{21}-a_{22}}{la_{21}}x_{1,2} + \frac{1}{l}x_{1,3}
\end{aligned}
\tag{5.37}
$$

Finally the budget allocations compatible to the given series of target supplies can be calculated from equation 5.34:

$$
\begin{aligned}
u_5 &= x_{6,1} - (1-\delta)x_{5,1} \\
u_4 &= x_{5,1} - (1-\delta)x_{4,1} \\
&\vdots \\
u_0 &= x_{1,1} - (1-\delta)x_{0,1}
\end{aligned}
\tag{5.38}
$$

The two assumptions concerning the smoothness of the demand trajectory and the size of the budget may not hold. Then demand cannot equal supply over the whole planning horizon. The results found should be used to check the validity of these assumptions.

Two separate tests are involved:

1. Is the budget constraint satisfied by the sequence of investments u_0 through u_5 as calculated, or is

$$\sum_{t=0}^{5} u_t \leqslant \bar{U} \ ? \tag{5.39}$$

2. Was the demand trajectory smooth enough so as not to force selling of training capacity, or is

$$u_t \geqslant 0 \ for \ t = 0,1,2,3,4,5? \tag{5.40}$$

If one of two or both tests belie the assumptions made, we would resort as a rule to a more general solution technique like quadratic programming (as will be given in the section entitled "Optimal Budget Allocations—A Quadratic Programming Problem"), in which the constraints of equations 5.39 and 5.40 are explicitly taken into account.

Optimal Budgeting under Erratic Demand for More than One Year

The use of quadratic programming for this relatively simple and structured problem is not always necessary. Instead, a solution can be found directly by simpler reasoning, if the budget constraint is not binding. Although we do not use quadratic programming for this one-year solution, we do need a quadratic objective function to permit deviation of target from actual supply in either direction.

We now permit the case of oversupply and therefore the need for restricting investment. It is intuitively clear that in the case of a theoretical solution of negative investment in a year $\hat{t}-4$ that the practical investment in that year will be zero. But as a result, the supply in the year $\hat{t}$, four years later, will

probably exceed the target supply. Suppose that in the original solution a positive investment $u_{\hat{t}-5}$ would have insured that the actual supply would exactly meet the target.

$$un_{\hat{t}-1} = \overline{un}_{\hat{t}-1} \tag{5.41}$$

The combination of this choice of $u_{\hat{t}-5}$ and $u_{\hat{t}-4} = 0$ will lead to deviations between actual and targeted supply of zero in year $\hat{t}-1$ and $\underline{b}$ in year $\underline{\hat{t}}$ (see Figure 5.1, dashed line). The quadratic objective function registers this deviation of an actual from a target. Now this deviation is equal to $pr_{\hat{t}}b^2$. The deviation of the actual from the target in year $\hat{t}$ would be less if, in the preceding year, some difference between actuals and targets would have been allowed. This situation is depicted in Figure 5.1 by the dotted and dashed line. All those controls, $u_{\hat{t},5}$ which insure that

$$(pr_{\hat{t}-1}c^2 + pr_{\hat{t}}a^2) \leqslant pr_{\hat{t}}b^2 \tag{5.42}$$

are better than the original choice of $u_{\hat{t}-5}$. That choice of $u_{\hat{t}-5}$ is optimal for which the sum $(pr_{\hat{t}-1}c^2 + pr_{\hat{t}}a^2)$ is minimal.

This solution procedure thus is based on the reasoning that the criterion is minimized by equalizing all actual supplies with target supplies. If this equalization is not feasible at a certain point of time, then the actual supply of the preceding year is adapted to make deviations minimal. However, demand is so erratic that it forces new investments to be negative but only at *one* point in time, and thus minimizes the criterion over those two years, *while for the rest of the planning period, actuals remain to match targets.*

The optimal control required to steer the actual supply of year $(\hat{t}-2)$ – which matches the target supply—to an actual supply of year $(\hat{t}-1)$, or $u_{\hat{t}-5}$, can be calculated as follows:

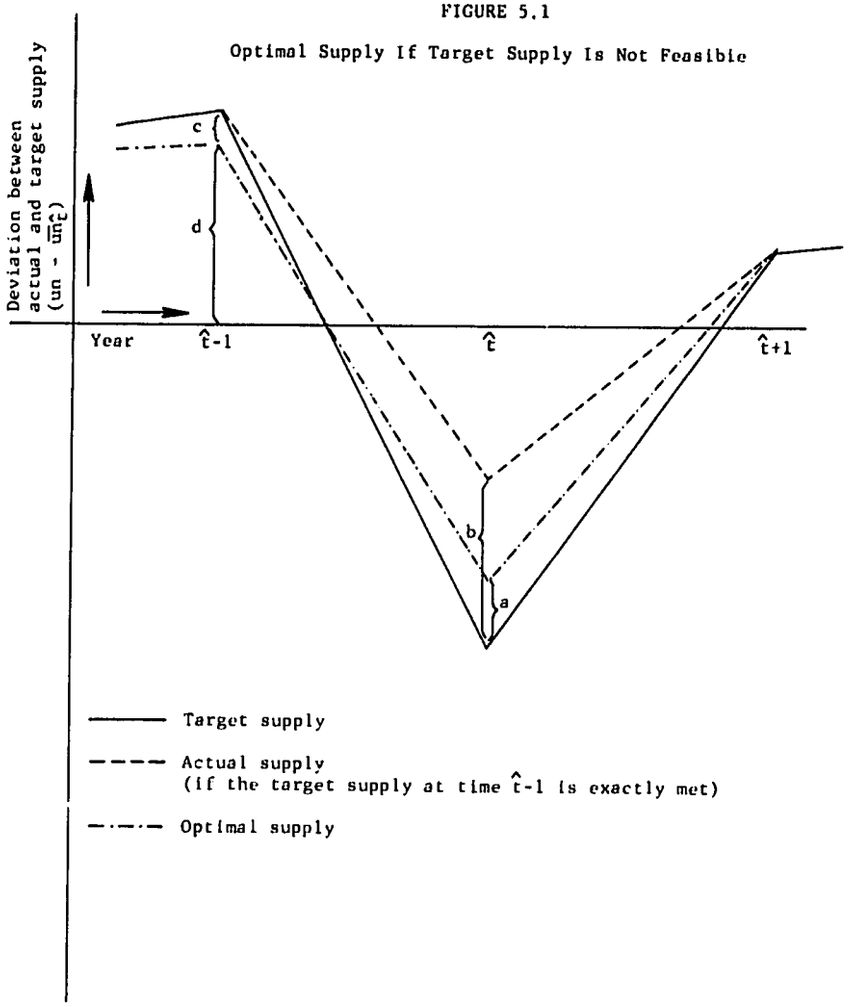
1. Express the actual supplies in the years $(\hat{t}-1)$ and $(\hat{t})$ in the initial conditions and the series of investments $u_0, u_1, u_2, \ldots, u_{\hat{t}-6}, u_{\hat{t}-5}, u_{\hat{t}-4}$.
2. It is known that $u_{\hat{t}-4}$ is minimal (zero). Consequently, the actual supplies can be expressed from the initial conditions, the series of investments $u_0, u_1, \ldots, u_{\hat{t}-6}$, and the unknown investment $u_{\hat{t}-5}$.
3. Choose $u_{\hat{t}-5}$ in order to minimize the criterion after the two years $(\hat{t}-1)$ and $\hat{t}$.

The mathematical formulation of this improvised solution can be found by expressing actual supplies in $(\hat{t}-1)$ and $\hat{t}$ in terms of the initial conditions and the investment trajectory, as follows:

Let us express the vector $\underline{x}$ at time $t=1$ in terms of $\underline{x}$ at time $t=0$, and the control at time $t=0$ with equation 5.18:

FIGURE 5.1

Optimal Supply If Target Supply Is Not Feasible



$$\underline{x}_1 = A\underline{x}_0 + \underline{b}u_0 \tag{5.43}$$

Similarly, the vector $\underline{x}$ of time $t=2$ can be expressed in the vector $\underline{x}$ at time $t=1$ and the investment of that time:

$$\underline{x}_2 = A\underline{x}_1 + \underline{b}u_1 \tag{5.44}$$

Now we can substitute equation 5.43 in equation 5.44 such that

$$\underline{x}_2 = A^2\underline{x}_0 + A\underline{b}u_0 + \underline{b}u_1 \tag{5.45}$$

Following this pattern the vector $\underline{x}$ at time $t=\hat{t}$ can be expressed in the vector $\underline{x}$ at time $t=0$ and the controls between $t=0$ and $t=\hat{t}-1$. Let us define the matrixes:

$$B_i = A^i \qquad for\ i = 0,1,2,\ldots,\hat{t} \tag{5.46}$$

The elements of matrix B_i are defined as follows:[9]

$$B_i = \begin{bmatrix} \beta_{11,i} & 0 & 0 & 0 \\ \beta_{21,i} & \beta_{22,i} & \beta_{23,i} & 0 \\ \beta_{31,i} & \beta_{34,i} & \beta_{33,i} & 0 \\ \beta_{41,i} & \beta_{42,i} & \beta_{43,i} & \beta_{44,i} \end{bmatrix} \tag{5.47}$$

Note that

$$B_0 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 \end{bmatrix} \tag{5.48}$$

and $B_1 \equiv A$ (5.49)

The manpower supply of time $\hat{t}$ thus is:

$$x_{\hat{t},4} = \beta_{41,\hat{t}}x_{0,1} + \beta_{42,\hat{t}}x_{0,2} + \beta_{43,\hat{t}}x_{0,3} + \beta_{44,\hat{t}}x_{0,4}$$

$$+ \beta_{41,\hat{t}-1}u_0 + \beta_{41,\hat{t}-2}u_1 + \cdots + \beta_{41,4}u_{\hat{t}-5} + \beta_{41,3}u_{\hat{t}-4} \quad (5.50)$$

$$= \sum_{i=1}^{4} \beta_{4i,\hat{t}}x_{0,i} + \sum_{i=0}^{t-4} \beta_{41,\hat{t}}u_i \quad (5.51)$$

If the target supply of year $\hat{t}$ requires that new investments in year $(\hat{t}-4)$ become negative, then in practice:

$$u_{\hat{t}-4} = 0 \quad (5.52)$$

The supply in year $\hat{t}$ is now expressed in the known set of initial conditions, the known set of investments over the period $t = 0$ to $t = \hat{t}-6$ and the unknown investment in year $(\hat{t}-5)$, $(u_{\hat{t}-5})$.

The supply in year $(\hat{t}-1)$ is expressed by:

$$x_{\hat{t}-1,4} = \sum_{i=1}^{4} \beta_{4i,\hat{t}-1}\, x_{0,i} + \sum_{i=0}^{\hat{t}-5} \beta_{41,\hat{t}-2-i}u_i \quad (5.53)$$

The control $u_{\hat{t}-5}$ is now optimal if the following expression is minimized:

$$W = pr_{\hat{t}-1}(x_{\hat{t}-1,4} - \bar{x}_{\hat{t}-1,4})^2 + pr_{\hat{t}}(x_{\hat{t},4} - \bar{x}_{\hat{t},4})^2 \quad (5.54)$$

The expression is minimal if the control satisfies the first time derivative of the expression with respect to the control to be zero:

$$\frac{\partial W}{\partial u_{\hat{t}-5}} = 0 \quad (5.55)$$

$$pr_{\hat{t}-1}\beta_{41,3}(x_{\hat{t}-1,4} - \bar{x}_{\hat{t}-1,4}) + pr_{\hat{t}}\beta_{41,4}(x_{\hat{t},4} - \bar{x}_{\hat{t},4}) = 0 \quad (5.56)$$

Let us define for convenience sake:

$$\psi = \frac{pr_{\hat{t}-1}\beta_{41,3}}{pr_{\hat{t}}\beta_{41,4}} \quad (5.57)$$

(We assume $pr_t > 0$).

The expression 5.56 then can be written to be:

$$\psi x_{\hat{t}-1,4} + x_{\hat{t},4} = \psi\bar{x}_{\hat{t}-1,4} + \bar{x}_{\hat{t},4} \quad (5.58)$$

This can be rewritten after substitution of equations 5.51 and 5.53 with the assumption that $u_{\hat{t}-4} = 0$ of equation 5.52 in terms of the unknown new investment, $u_{\hat{t}-5}$, and other unknown terms:

$$(\psi\beta_{41,3} + \beta_{41,4})u_{\hat{t}-5} = 4\bar{x}_{\hat{t}-1,4} + \bar{x}_{\hat{t},4} - \sum_{i=1}^{4}(\psi\beta_{4i,\hat{t}-1} + \beta_{4i,\hat{t}})x_{0,i} - \sum_{i=0}^{\hat{t}-5}(\psi\beta_{41,\hat{t}-2-i} + \beta_{41,\hat{t}-1-i})u_i \tag{5.59}$$

The solution becomes somewhat more complicated if the decrease of the supply follows a longer-term trend. Particularly, the situation may arise that the optimal investment in year $(\hat{t}-5)$ with respect to the feasibility of one target supply in year $\hat{t}$ as discussed renders a negative investment in that year $(\hat{t}-5)$. To solve this problem the same reasoning can be followed and the optimal investment in year $(\hat{t}-6)$ can be computed under the assumption that both the investments in the years $\hat{t}-5$ and $\hat{t}-4$ are the minimum feasible investments, that is, zero. The general solution to such problems will be given in the following section using quadratic programming. The procedures that we have just outlined thus allow us to calculate the optimal series of investments required to meet the target supplies as closely as possible over the planning period, if the budget constraint is not binding, whatever the shape of the demand trajectory.

OPTIMAL BUDGET ALLOCATIONS— A QUADRATIC PROGRAMMING PROBLEM

Statement and Solution of the Problem

This time we shall proceed to consider the nonlinear programming problem in full without making any assumptions concerning the smoothness of the demand trajectory or whether the budget constraint is binding or not. Also, we shall consider explicitly in this section different technologies $\underline{k}$ and different institutes (or regions) $\underline{i}$ where graduates are trained, adding theoretically two subscripts to the equations. A reduction with one subscript can be accomplished by combining the subscripts for technology $\underline{k}$ and region $\underline{i}$ into one "station" subscript $\underline{p}$ such that

$p = 1$ *if* $i = 1$ *and* $k = 1$

$p = 2$ *if* $i = 2$ *and* $k = 1$

$p = 4 \quad if \quad i = 4 \ and \ k = 1$

$p = 5 \quad if \quad i = 1 \ and \ k = 2$

.
.
.

$p = 9 \quad if \quad i = 1 \ and \ k = 3$

etc.

The optimal budget allocation problem is then defined to be:

$$\text{Minimize} \sum_{t=4}^{T+4} \sum_{p=1}^{q} pr_{t,p}(x_{t,4,p} - \bar{x}_{t,4,p})^2 \tag{5.60}$$

where T is the length of the planning period, q is the total number of sections, and $pr_{t,p}$ is the preference for attaining the maximum target in year t in station p subject to the constraints.

1. System equations:

$$\underline{x}_{t+1,p} = A\underline{x}_{t,p} + \underline{b}_p u_{t,p} \tag{5.61}$$

2. The control inequality:

$$u_{t,p} \geqslant 0 \tag{5.62}$$

3. Budget constraints:

$$\sum_{t=0}^{T} \sum_{p=1}^{q} u_{t,p} \leqslant U \tag{5.63}$$

As shown in equation 5.51, the stock of graduates s in a year t can be expressed analytically in the initial conditions and the flow of investments from $t=0$ through $t=t-4$:

$$\bar{x}_{t,4,p} = \sum_{i=1}^{4} \beta_{4i,t,p} x_{0,i,p} + \sum_{i=0}^{t-4} \beta_{41,t-i-1,p} u_{i,p} \tag{5.64}$$

Thus the difference between actual and desired stock can be written as

$$x_{t,4,p} - \bar{x}_{t,4,p} = \sum_{i=0}^{t-4} \beta_{41,t-i-1,p} u_{i,p} + bx_{t,p} \tag{5.65}$$

where

$$bx_{t,p} = \sum_{i=1}^{4} \beta_{4i,t,p}\, x_{0,i,p} - \bar{x}_{t,4,p} \tag{5.66}$$

The programming problem is then—after writing out equation 5.60 with 5.65—defined as follows:

$$\begin{aligned}\text{Minimize } & \sum_{p=1}^{q} pr_{4,p}\,(\beta_{41,3,p}\, u_{0,p} + bx_{4,p})^2 \\ & + pr_{5,p}\,(\beta_{41,4,p}\, u_{0,p} + \beta_{41,3,p}\, u_{1,p} + bx_{5,p})^2 \\ & + pr_{6,p}\,(\beta_{41,5,p}\, u_{0,p} + \beta_{41,4,p}\, u_{1,p} + \beta_{41,3,p}\, u_{2,p} + bx_{6,p})^2 \\ & + \cdots + pr_{T+4,p}\,(\beta_{41,T+3,p}\, u_{0,p} + \beta_{41,T+2,p}\, u_{1,p} + \cdots \\ & + \beta_{41,3,p}\, u_{T,p} + bx_{T+4,p})^2 \end{aligned} \tag{5.67}$$

This criterion can be written as:

$$\text{Minimize } \sum_{p=1}^{q} (\underline{u}'_p\, S_p \underline{u}_p + 2\underline{r}'_p\, \underline{u}_p) + \text{ a term that is beyond control.} \tag{5.68}$$

Here the apostrophe sign (') denotes the transpose of a vector, while the vector $\{\underline{u}_p = u_{0,p} u_{1,p} \cdots, u_{T,p}\}$ is of dimension (T + 1). The matrix S_p is symmetric and is shown in Figure 5.2. S_p is square and of dimension $(T + 1)$. An element of S_p in the k'th row and the j'th column is to be denoted by $s_{kj,p}$; so that

$$s_{k,j,p} = \sum_{i=3}^{T+4-j} \beta_{41,i+j-k,p}\, \beta_{41,i,p}\, pr_{i+j,p} \tag{5.69}$$

The vector function $\underline{r}_p$ is equivalent to:

$$\underline{r}_p = \begin{bmatrix} \sum_{i=3}^{T+2} bx_{i+1,p} \quad \beta_{41,i,p} pr_{i+1} \\ \sum_{i=3}^{T+2} bx_{i+2,p} \quad \beta_{41,i,p}\, pr_{i+2} \\ \vdots \\ \sum_{i=3}^{T+2} bx_{T+3,p} \quad \beta_{41,2,p}\, pr_{T+3} \end{bmatrix} \tag{5.70}$$

Equation 5.67 can now be used to replace the original set consisting of the objective function of equation 5.60 and the systems equations of equation 5.61. The constraints on the control equations 5.62 and 5.63 remain, however, forming with equation 5.67 the quadratic programming problem.

FIGURE 5.2

Matrix S_p

$$S_p = b_p^2 \begin{bmatrix} \sum_{i=2}^{T+2} pr_{i+1,p}(\beta_{31,i,p})^2 & \sum_{i=2}^{T+1} pr_{i+2,p}(\beta_{31,i+1,p}\beta_{31,i,p}) & \sum_{1=2}^{T} pr_{i+3,p}\beta_{31,i+2,p}\beta_{31,i,p} \cdots pr_{T+3,p}\beta_{31,T+2,p}\beta_{31,2,p} \\ \cdot & & \\ \cdot \cdot \cdot \cdot & \sum_{i=2}^{T+1} pr_{i+2,p}(\beta_{31,i,p})^2 & \sum_{i=2}^{T} pr_{i+3,p}\beta_{31,i+1,p}\beta_{31,i,p} \cdots pr_{T+3,p}\beta_{31,T+1,p}\beta_{31,2,p} \\ \cdot & \cdot & pr_{T+3,p}\beta_{31,T,p}\beta_{31,2,p} \\ \cdot & \cdot & \\ & \cdot & \\ & & \cdot \\ & & \cdot \\ & & \cdot \\ & & \cdot \\ & & \cdot \\ & & \cdot \\ \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot & & pr_{T+3,p}(\beta_{31,2,p})^2 \end{bmatrix}$$

The constraint on "disinvestments," or selling off of capacity can be considerably relaxed, if desired. Rather than using the inequality constraint of equation 5.62, we shall demand that

$$x_{t,1} \geqslant 1/l(x_{t,2} + x_{t,3}) \tag{5.71}$$

Disinvestments are now allowed up to the point where enrollments in the first-year class become zero.

The new—implicit—minimum constraint on annual investments of equation 5.71 can be written as an explicit constraint. For this operation we shall omit the station subscript p:

$$u_{\hat{t}-1} \geqslant 1/l(x_{\hat{t},2} + x_{\hat{t},3}) - (1-\delta)x_{\hat{t}-1,1} \tag{5.72}$$

Now each of the right-hand-side variables of equation 5.71 can be expressed with equation 5.18 in the initial conditions and the set of investments from $t=0$ through $t=\hat{t}-2$:

$$x_{\hat{t},2} = \sum_{i=1}^{3} (\beta_{2i,\hat{t}} x_{0,i}) + \sum_{i=0}^{\hat{t}-2} (\beta_{21,\hat{t}-1-i} u_i) \tag{5.73}$$

$$x_{\hat{t},3} = \sum_{i=1}^{3} (\beta_{3i,\hat{t}} x_{0,i}) + \sum_{i=0}^{\hat{t}-2} (\beta_{31,\hat{t}-1-i} u_i) \tag{5.74}$$

$$\hat{x}_{t-1,1} = (1-\delta)^{\hat{t}-1} x_{0,1} + \sum_{i=0}^{\hat{t}-2} (1-\delta)^{\hat{t}-i-2} u_i \tag{5.75}$$

Substitution of equations 5.73 through 5.75 in equation 5.72 gives:

$$\begin{aligned} u_{\hat{t}-1} - \sum_{i=0}^{\hat{t}-2} \left\{ 1/l(\beta_{21,\hat{t}-1-i} + \beta_{31,\hat{t}-1-i}) - (1-\delta)^{\hat{t}-i-1} \right\} u_i \\ \geqslant 1/l \sum_{i=1}^{3} (\beta_{2i,\hat{t}} + \beta_{3i,\hat{t}}) x_{0,i} - (1-\delta)^{\hat{t}} x_{0,1} \end{aligned} \tag{5.76}$$

Equation 5.75 can now be written in matrix form as:

$$V\underline{u} \geqslant \underline{w} \tag{5.77}$$

The matrix V is square and of dimension $(T+1)$. The upper triangle of the matrix contains only zeros, the diagonal only *ones*, and the elements on lines parallel to the diagonal in the lower triangle are equal to

$$v_{k,j} = 0 \qquad \text{if } j > k$$

$$= 1 \qquad \text{if } j = k \tag{5.78}$$

$$v_{k,j} = v_{k+1,j+1} \qquad \text{if } j < k$$

while

$$v_{k,j} = \left\{ -(\beta_{21,k-j} + \beta_{31,k-j})/d + (1-\delta)^{k-j} \right\} \tag{5.79}$$

A typical element j of vector $\underline{w}$ is

$$w_j = 1/l \sum_{i=1}^{3} (\beta_{2i,j} + \beta_{3i,j}) x_{0,i} - (1-\delta)^j x_{0,i} \tag{5.80}$$

This can be checked by writing out equation 5.77 for the minimum investment constraints for a number of years:

1. Investment constraint for time $t = 0$, $i = 1$

$$u_0 \geqslant 1/l \sum_{i=1}^{3} (\beta_{2i,1} + \beta_{3i,1}) x_{0,i} - (1-\delta) x_{0,1} \tag{5.81}$$

2. Budget constraint:

$$\sum_{t=0}^{T} \sum_{p=1}^{q} u_{t,p} \leqslant \bar{U}, \quad \textit{which was equation 5.63.}$$

3. Minimum budget allocations:

$$V_p \underline{u}_p \geqslant \underline{w}_p, \quad \textit{which was equation 5.77.}$$

Matrixes S and V are given in Figures 5.2 and 5.3 respectively.

Quadratic programming problems are extensively described in the operations research literature.[10] Several algorithms for the solution of these problems have been developed. For this study we shall use a subroutine developed by the computer center of the University of California (Berkeley) based on the Lemke-Howson algorithm for which the matrix S must either have all elements positive, have positive principle minors, or be positive semidefinitely.[11]

A Numerical Example

A numerical example using Bangladesh data will be given to demonstrate how to use the decision model as a means of calculating the optimal investments with respect to the objectives of the government agency, in this case, the Directorate of Technical Education. The values of the coefficients and the initial conditions will be chosen as realistically as possible.

FIGURE 5.3

Matrix V_p

$$V_p = \begin{bmatrix} 1 & 0 & \cdot & \cdot & \cdot & \cdot & 0 \\ -\frac{1}{l_p} b_p(\beta_{11,0,p} + \beta_{21,0,p}) & 1 & & & & & \\ -\frac{1}{l_p} b_p(\beta_{11,1,p} + \beta_{21,1,p}) & -\frac{1}{l_p} b_p(\beta_{11,0,p} + \beta_{21,0,p}) & \cdot & \cdot & \cdot & \cdot & 0 \\ & & \cdot & & & & \\ \cdot & \cdot & & \cdot & & & 0 \\ \cdot & \cdot & & & \cdot & & 0 \\ \cdot & \cdot & & & & \cdot & 0 \\ -\frac{1}{l_p} b_p(\beta_{11,T-1,p} + \beta_{21,T-1,p}) & -\frac{1}{l_p} b_p(\beta_{11,T-2,p} + \beta_{21,T-2,p}) & & & & & 1 \end{bmatrix}$$

Before choosing values for the coefficients, the initial conditions, and the duration of the planning period, we shall outline the steps taken in the computation of the optimal investments.

Step 1

Compute the minimum feasible supply of graduates resulting from the initial conditions, that is, if investments lead to zero enrollments in the first equation. This step does not require knowledge of the trajectory of target supplies. Target supplies should always exceed the minimum feasible supply, which is computed in this step.

Step 2

Given the trajectory of target supplies, calculate enrollments and subsequently the new investments required to fund the student places calculated. This calculation follows the recursive equations of a previous section of this chapter (see "Optimal Budgeting under Erratic Demand for More Than One Year"). If (1) all new investments calculated are positive, (2) all preferences are equal, and (3) the budget constraints are satisfied—or if no budget constraints exist—then the optimal budget allocation is acquired from this step.

Step 3

If one or more of the above-mentioned conditions is not satisfied we can treat the optimal resource allocation problem as a quadratic programming problem. The structure of the computer program to calculate the optimal budget allocations that satisfy the constraints of the minimum investment (which lead to zero enrollments in the first-year class) and of the maximum budget (which has been specified) is given in Figure 5.4. Notice that the target supplies are required solely to compute the value of the vector functions $\underline{r}_p$ (the terms in the criterion that are linear in the control). In the same step the optimal investment allocations are used to compute the enrollments and the stock over the planning period in each of the stations. This third and last step can be taken without going through Steps 1 and 2 since the quadratic programming problem is the most generalized form of this manpower planning problem.

The following set of values is chosen for the numerical example: The planning period considered is five years. The number of stations considered is four. The elements of the matrixes A_p $(p = 1,2,3,4)$ are given in Table 5.2. The value of the first and only nonzero elements of the vectors $\underline{b}_p$ of equation 5.80 is the same for all stations and is equal to one. The depreciation rate of

FIGURE 5.4

Structure of Computer Program for the Quadratic Manpower Planning Problem

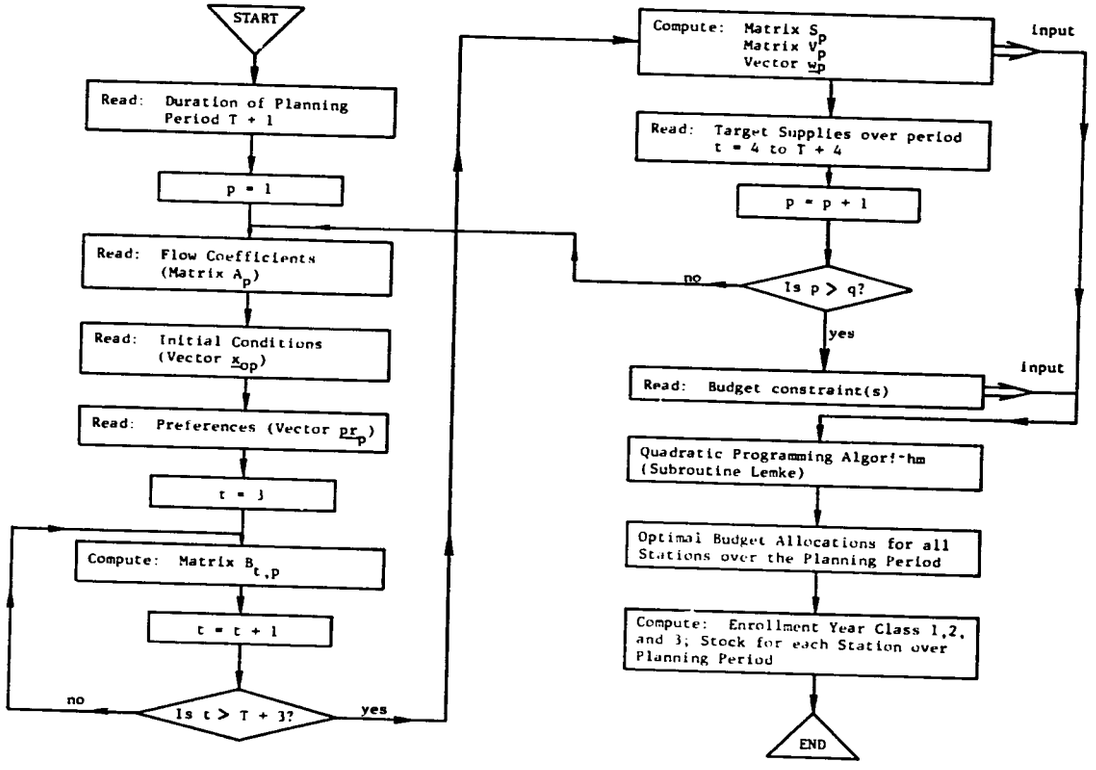


TABLE 5.2

Matrixes A_p

$$A_1 = \begin{bmatrix} .90 & 0 & 0 & 0 \\ .00162 & -.61 & -.66 & 0 \\ 0 & .85 & .10 & 0 \\ 0 & 0 & .77 & .99 \end{bmatrix}$$

$$A_2 = \begin{bmatrix} .90 & 0 & 0 & 0 \\ .00162 & -.61 & -.66 & 0 \\ 0 & .70 & .10 & 0 \\ 0 & 0 & .76 & .99 \end{bmatrix}$$

$$A_3 = \begin{bmatrix} .90 & 0 & 0 & 0 \\ .00162 & -.61 & -.66 & 0 \\ 0 & .80 & .10 & 0 \\ 0 & 0 & .60 & .99 \end{bmatrix}$$

$$A_4 = \begin{bmatrix} .90 & 0 & 0 & 0 \\ .00162 & -.61 & -.66 & 0 \\ 0 & .75 & .10 & 0 \\ 0 & 0 & .76 & .99 \end{bmatrix}$$

capital has been put to be 10 percent, such that $(1-\delta) = .90$. The capital costs per student are estimated to be Rs. 407 so that $a_{21} = .66/407 = .00162$. Both values are considered to be independent of technology or region. The matrix C_p is the same for all stations:

Matrix C_p

$$C_p = \begin{bmatrix} .243 & -1 & 0 \\ 2.64 & 0 & 0 \\ .0008 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} \qquad \text{for } p = 1, 2, 3, 4$$

Recurring costs per student and teacher-student ratios are considered to be equal for all classes, and are Rs. 1,079 and .33 respectively. The initial conditions for each of the four stations are:

$$\text{Station 1: } \underline{x}_{0,1} = \begin{bmatrix} 915{,}343 \\ 662 \\ 500 \\ 2{,}310 \end{bmatrix} \qquad \text{Station 2: } \underline{x}_{0,2} = \begin{bmatrix} 470{,}085 \\ 352 \\ 269 \\ 1{,}155 \end{bmatrix}$$

$$\text{Station 3: } \underline{x}_{0,3} = \begin{bmatrix} 1{,}030{,}524 \\ 765 \\ 600 \\ 1{,}027 \end{bmatrix} \qquad \text{Station 4: } \underline{x}_{0,4} = \begin{bmatrix} 914{,}122 \\ 686 \\ 522 \\ 1{,}201 \end{bmatrix}$$

This choice of coefficients and initial conditions is based on the Bangladesh data recorded in the preceding chapters. We argue that these data are realistic for the five-year planning period 1972/73 to 1977/78, leading to a stock formation until 1981. The four stations represent the four major technologies—civil, electrical, mechanical, and power engineering—aggregated over all polytechnics of Bangladesh. The results of this numerical example are as follows:

Step 1

The minimum supply trajectory of the four stations feasible with the initial conditions and the flow coefficients specified is recorded in Table 5.3.

Step 2

This step requires the specification of target supplies. Two trajectories are chosen: one trajectory (I) is characterized by a smoothly increasing target; another trajectory (II) of target supplies is erratic. These target supplies are given in Table 5.4. The investment and the enrollments required to meet these target supplies are in Table 5.5 for trajectory I and Table 5.6 for trajectory II. All enrollments for trajectory I are feasible under the constraint of maximum disinvestments allowed of equation 5.77. All target supplies are met exactly if no budget constraints are imposed. Trajectory II, however, requires enrollments to become negative in order to meet the target supplies, or in other words, not all target supplies can be met.

Step 3

1. We shall apply this step first to the erratic trajectory of target supplies (trajectory II) without imposing budget constraints and consider subsequently trajectory I under budget constraints while all preferences pr_p remain equal.

There is no interrelationship in meeting the erratic target supply trajectories of the four stations simultaneously. Thus, the optimal investments can be

TABLE 5.3

Minimum Target Supplies Feasible, 1972-80

Year	Class 1	Class 2	Class 3	Stock	Total Investments	Recurring Costs	Teachers
Station 1							
1972	999	662	588	2,318	915,343	2,426,671	75
1973	0	666	622	2,748	524,216	1,389,752	42
1974	0	33	628	3,199	269,027	713,219	22
1975	0	1	90	3,650	37,037	98,189	3
1976	0	0	9	3,682	3,663	9,711	0
1977	0	0	0	3,652	0	0	0
1978	0	0	0	3,615	0	0	0
1979	0	0	0	3,578	0	0	0
1980	0	0	0	3,542	0	0	0
Station 2							
1972	534	352	269	642	470,085	1,246,245	39
1973	0	356	291	840	263,329	698,113	21
1974	0	17	278	1,052	120,065	318,305	9
1975	0	0	39	1,252	15,873	42,081	1
1976	0	0	3	1,269	1,221	3,237	0
1977	0	0	0	1,258	0	0	0
1978	0	0	0	1,245	0	0	0
1979	0	0	0	1,232	0	0	0
1980	0	0	0	1,219	0	0	0
Station 3							
1972	1,159	765	608	1,027	1,030,524	2,732,028	84
1973	0	772	673	1,382	588,115	1,559,155	48
1974	0	38	684	1,771	293,854	779,038	24
1975	0	1	98	2,163	40,293	106,821	3
1976	0	0	10	2,200	4,070	10,790	0
1977	0	0	1	2,183	407	1,079	0
1978	0	0	0	2,161	0	0	0
1979	0	0	0	2,139	0	0	0
1980	0	0	0	2,117	0	0	0
Station 4							
1972	1,038	686	522	1,201	914,122	2,423,434	75
1973	0	691	567	1,586	512,006	1,357,382	41
1974	0	34	574	2,001	247,456	656,032	20
1975	0	1	82	2,417	33,781	89,557	2
1976	0	0	8	2,455	3,256	8,632	0
1977	0	0	0	2,436	0	0	0
1978	0	0	0	2,411	0	0	0
1979	0	0	0	2,386	0	0	0
1980	0	0	0	2,362	0	0	0

TABLE 5.4

Target Supplies, 1976/77-1980/81

	Station 1		Station 2		Station 3		Station 4	
Year	Traj.* I	Traj. II	Traj. I	Traj. II	Traj. I	Traj. II	Traj. I	Traj. II
1976/77	4,100	4,750	1,450	1,800	2,550	3,000	2,800	3,600
1977/78	4,550	4,000	1,650	2,600	2.950	2,600	3,200	3,200
1978/79	5,000	4,750	1,850	2,200	3,350	3,800	3,600	2,800
1979/80	5,450	5,750	2,050	2,150	3,750	3,000	4,000	3,600
1980/81	5,900	5,900	2,250	2,250	4,150	4,150	4,400	4,400

*Trajectory.

calculated separately for each station. The optimal investments are shown in Table 5.7. Investments, recurring costs, and the number of teachers required in every year are calculated.

As mentioned in the section on optimal budgeting under erratic demand, the quadratic programming algorithm would not necessarily have to be used to calculate the optimal investments. This section provides the base for an algorithm that would require considerably fewer calculations. The structure of such an algorithm is shown in Figure 5.5. This algorithm can only be used if the budget is unconstrained. That implies, however, that the algorithm can be applied to each station independently.

To illustrate the numbers involved in the examples, Figures 5.6 to 5.9 are drawn to relate the minimum supply feasible to the target supplies (trajectories I and II) and to the actual supply of trajectory II.

2. Budget constraints imposed on the availability of investments essentially change the structure of the optimal allocation problem. The calculation of the optimal investment allocations for an erratic target supply trajectory (no budget constraints) required, in general, a single-step iterative search: If the theoretical investment allocation in a year $(t-2)$ would force the enrollment in the first-year class in year t to become negative, then this investment was adjusted. The new optimal investment could then be calculated in a single step with the algorithm, the structure of which is given in Figure 5.5.

The iterative search for the optimal investment allocations for the system considered under budget constraints takes more steps of subsequent adjustment. For the quadratic criterion (or utility function) we have assumed a quadratic programming solution is required to find the optimal investment allocations.

As an example, let us consider the same four stations and let the parameters (coefficients) of the systems equation remain as in the examples without budget constraints. All preferences pr_p also remain equal to one. The target supplies

TABLE 5.5

Recursive Calculation of Investments and Enrollments—Trajectory I, 1972-80

Year	Class 1	Class 2	Class 3	Stock	Total Depreciated Investments	Recurring Costs	New Investments	Teachers
Station 1								
1972	999	662	508	2,318	915,343	2,426,671	90,313	75
1973	960	665	621	2,748	914,122	2,423,434	99,959	74
1974	972	667	628	3,199	922,669	2,446,093	99,593	75
1975	980	675	630	3,651	929,995	2,465,515	84,941	75
1976	989	681	637	4,100	938,949	2,489,253	102,849	76
1977	999	687	643	4,550	947,903	2,512,991		77
1978		694	649	5,000				
1979			655	5,450				
1980				5,900				
Station 2								
1972	534	352	269	642	470,085	1,246,245	47,416	39
1973	512	354	290	840	470,492	1,247,324	47,049	38
1974	523	356	277	1,052	470,492	1,247,324	50,712	38
1975	525	363	277	1,252	474,155	1,257,035	52,707	38
1976	531	365	282	1,450	479,446	1,271,062	52,829	39
1977	537	369	284	1,650	484,330	1,284,010		39
1978		373	287	1,850				
1979			290	2,050				
1980				2,250				
Station 3								
1972	1,159	765	608	1,027	1,030,524	2,732,028	105,901	84
1973	1,100	768	671	1,382	1,033,373	2,739,581	128,970	84
1974	1,155	765	682	1,771	1,059,014	2,807,558	121,774	86
1975	1,159	801	681	2,163	1,074,887	2,849,639	124,990	87
1976	1,170	805	709	2,550	1,092,388	2,896,036	119,007	89
1977	1,180	813	715	2,950	1,102,156	2,921,932		89
1978		820	722	3,350				
1979			729	3,750				
1980				4,150				
Station 4								
1972	1,038	686	522	1,201	914,122	2,423,434	58,445	75
1973	911	688	566	1,586	881,155	2,336,035	97,884	71
1974	980	636	573	2,001	890,923	2,361,931	91,534	72
1975	981	679	535	2,417	893,365	2,368,405	105,617	72
1976	990	682	563	2,800	909,645	2,411,565	99,105	74
1977	999	688	568	3,200	917,785	2,433,145		74
1978		694	573	3,600				
1979			578	4,000				
1980				4,400				

TABLE 5.6

Recursive Calculation of Investments and Enrollments—Trajectory II, 1972-80

Year	Class 1	Class 2	Class 3	Stock	Total Investments	Recurring Costs	Teachers
Station 1							
1972	999	662	588	2,318	915,343	2,426,671	75
1973	2,466	664	621	2,748	1,526,657	4,047,329	124
1974	-2,013	1,661	627	3,199	111,925	296,725	9
1975	2,083	-1,246	1,475	3,650	940,984	2,494,648	76
1976	2,141	1,313	- 912	4,750	1,034,594	2,742,818	84
1977	124	1,479	1,025	4,000	1,069,596	2,835,612	87
1978		156	1,360	4,750			
1979			269	5,750			
1980				5,900			
Station 2							
1972	534	352	269	642	470,085	1,246,245	39
1973	1,508	354	290	840	875,864	2,322,008	71
1974	2,091	1,013	277	1,052	1,376,067	3,648,099	112
1975	-1,405	1,431	737	1,252	310,541	823,277	25
1976	92	- 856	1,076	1,800	126,984	336,648	10
1977	350	18	- 492	2,600	- 50,468	- 133,796	- 4
1978		232	- 36	2,200			
1979			159	2,150			
1980				2,250			
Station 3							
1972	1,159	785	608	1,027	1,030,524	2,732,028	84
1973	2,522	768	671	1,382	1,612,127	4,273,919	131
1974	-1,565	1,703	682	1,771	333,740	884,780	27
1975	4,056	- 948	1,431	2,163	1,847,373	4,897,581	150
1976	-2,988	2,630	- 616	3,000	- 396,418	-1,050,946	-32
1977	4,103	-1,841	2,043	2,600	1,752,135	4,645,095	142
1978		2,616	-1,269	3,800			
1979			1,966	3,000			
1980				4,150			
Station 4							
1972	1,038	606	522	1,201	914,122	2,423,434	74
1973	3,038	688	566	1,586	1,746,844	4,631,068	142
1974	-1,440	2,040	573	2,001	477,411	1,265,667	39
1975	- 815	- 849	1,588	2,417	-30,932	- 82,004	-3
1976	2,340	- 581	- 478	3,600	521,367	1,382,199	42
1977	1,885	1,516	- 484	3,200	1,187,219	3,147,443	96
1978		1,320	1,089	2,800			
1979			1,099	2,600			
1980				4,400			

TABLE 5.7

Optimal Investments, Trajectory II, 1972-80
(computed with quadratic programming algorithm)

Year	Class 1	Class 2	Class 3	Stock	Total Investments	Recurring Costs	New Investments	Teachers
Station 1								
1972	966	662	588	2,318	915,343	2,426,671	297,069	75
1973	1,466	666	622	2,748	1,120,878	2,971,566	-345,707	91
1974	1	1,000	628	3,199	663,003	1,757,691	175,376	54
1975	935	50	912	3,650	772,079	2,046,863	539,967	63
1976	2,282	619	133	4,315	1,234,838	3,273,686	-216,768	101
1977	122	1,537	539	4,374	894,586	2,371,642		73
1978		157	1,360	4,745				
1979			269	5,744				
1980				5,893				
Station 2								
1972	534	352	269	642	470,085	1,246,245	506,512	39
1973	1,637	356	291	840	929,588	2,464,436	134,473	76
1974	1,010	1,098	278	1,052	971,102	2,574,494	-256,573	79
1975	0	721	796	1,252	617,419	1,636,843	-303,337	50
1976	0	36	584	1,844	252,340	668,980	-192,251	20
1977	1	1	83	2,269	34,595	91,715		2
1978		0	8	2,309				
1979			0	2,291				
1980				2,268				
Station 3								
1972	1,159	765	608	1,027	1,030,524	2,732,028	405,453	84
1973	1,830	772	673	1,382	1,332,925	3,533,725	-413,716	109
1974	1	1,246	684	1,771	785,917	2,083,549	417,623	64
1975	1,637	62	1,065	2,163	1,124,948	2,982,356	-508,180	92
1976	0	1,083	156	2,780	504,273	1,336,881	928,733	41
1977	2,462	54	881	2,845	1,382,579	3,665,363		113
1978		1,627	131	3,345				
1979			1,314	3,390				
1980				4,144				
Station 4								
1972	1,038	686	522	1,201	914,122	2,423,434	422,710	75
1973	1,802	691	567	1,586	1,245,420	3,301,740	-389,092	102
1974	1	1,223	574	2,001	731,786	1,940,042	236,955	59
1975	1	61	974	2,417	421,652	1,117,844	152,869	34
1976	1,162	3	143	3,133	532,356	1,411,332	672,690	43
1977	2,047	767	16	3,210	1,151,810	3,053,570		94
1978		1,389	576	3,190				
1979			1,099	3,595				
1980				4,394				

FIGURE 5.5

Structure of Algorithm for the Solution of Optimal Investments under Erratic Target Supplies Without Budget Constraints

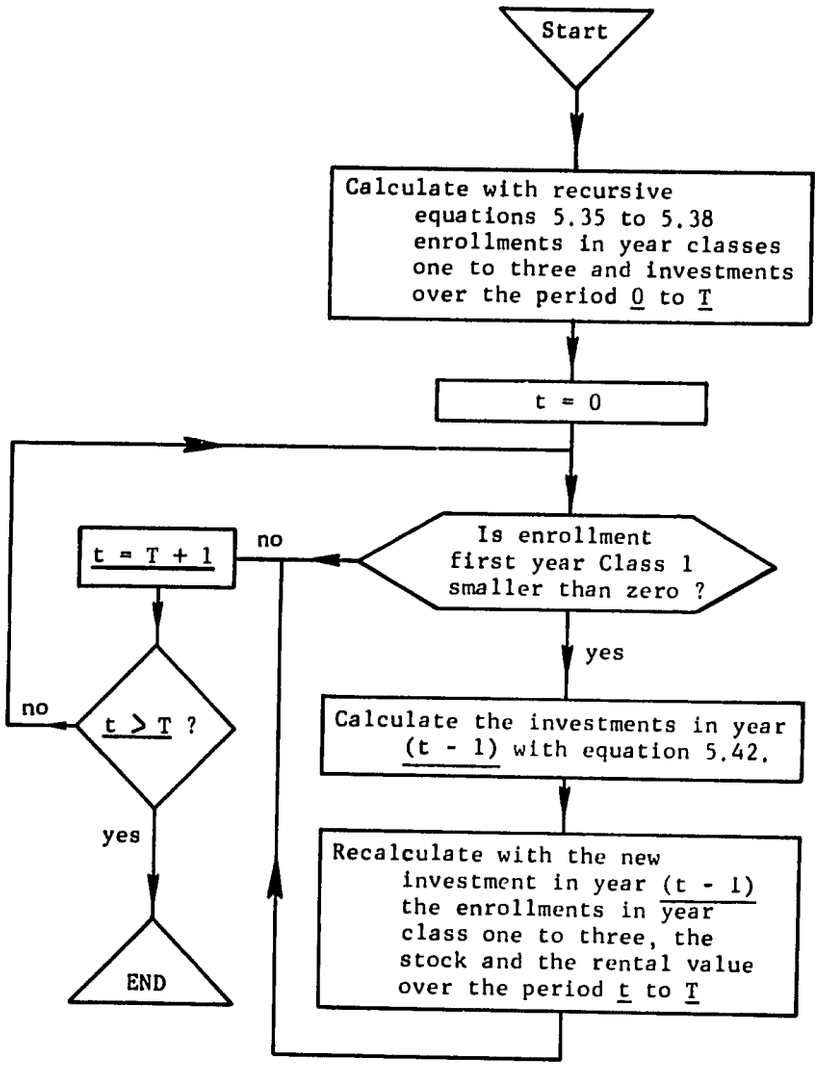


FIGURE 5.6

Supply Trajectories: Station 1

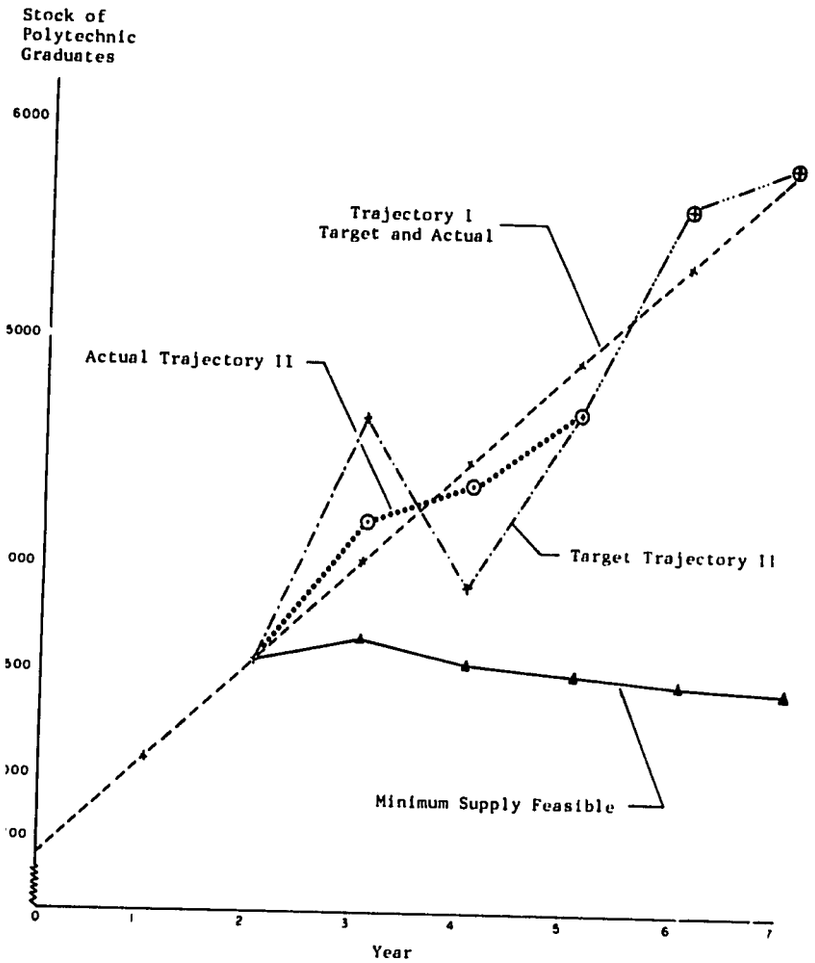


FIGURE 5.7

Supply Trajectories: Station 2

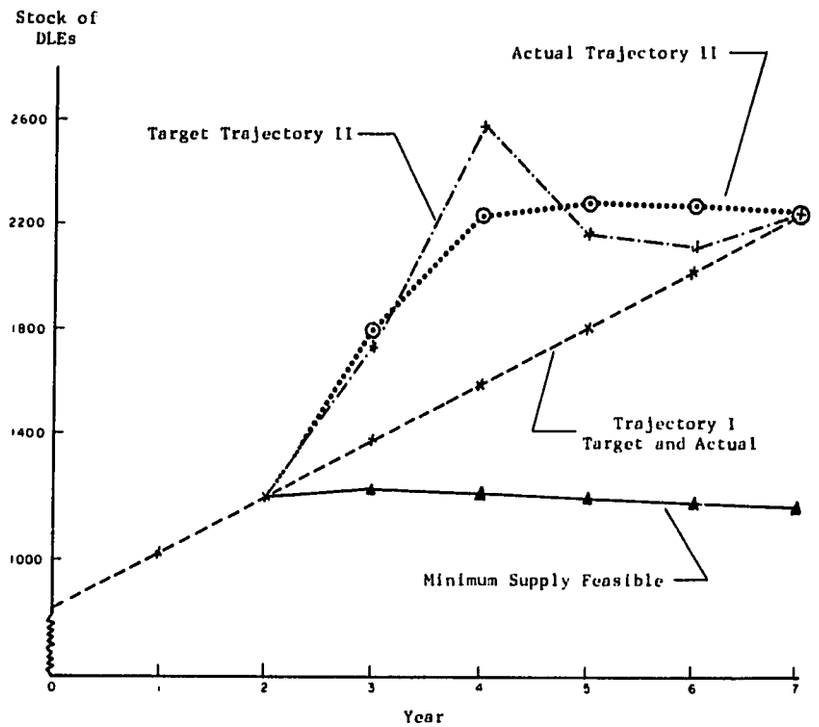


FIGURE 5.8

Supply Trajectories: Station 3

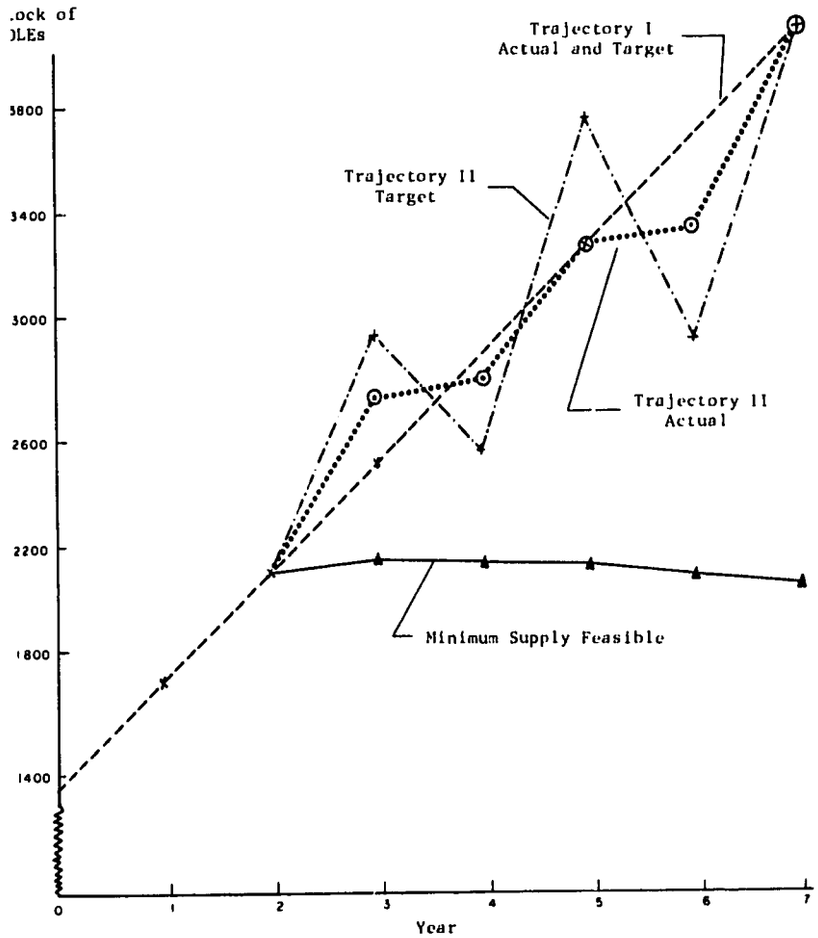
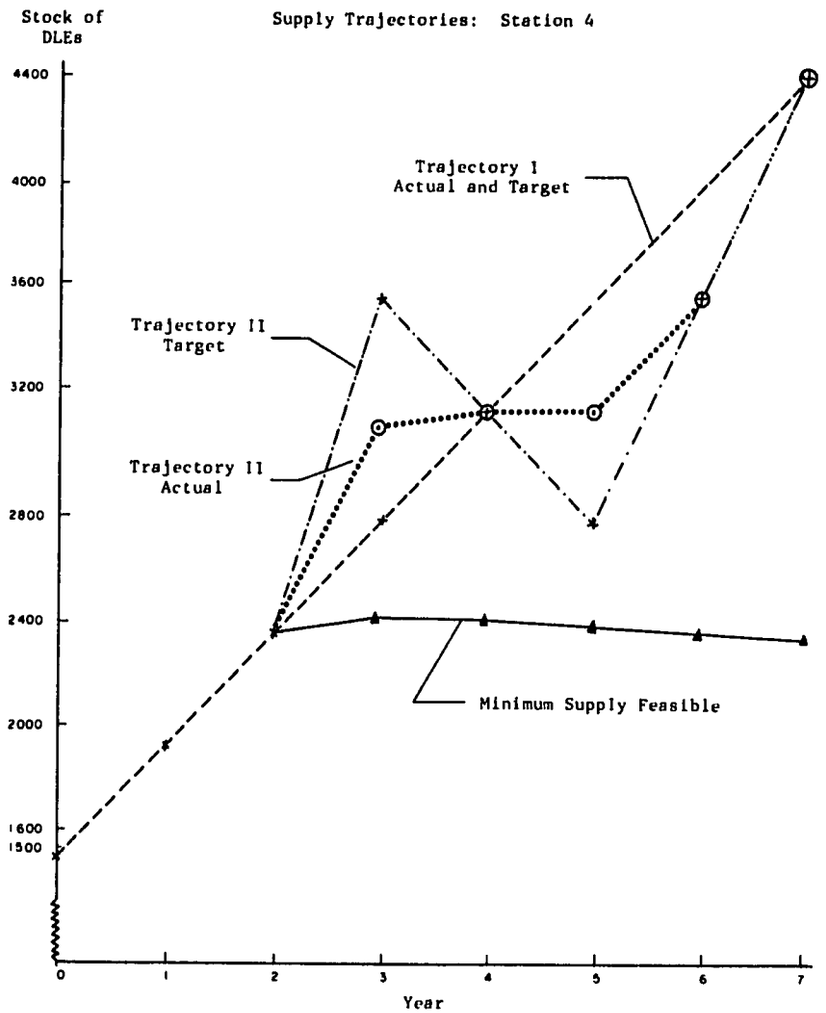


FIGURE 5.9

Supply Trajectories: Station 4



are specified by trajectory I. The total budget required to satisfy the needs for investments over the five-year planning period can be calculated from Table 5.5 and is approximately Rs. 1.70 million for all stations. We now calculate the optimal investment allocations if the budget is limited to Rs. 1.64 million.

The solution to this problem is shown in Table 5.8 and Figure 5.10. The optimal investments are used to calculate the enrollments, manpower accumulation, recurring costs, and teacher requirements. This solution is far from trivial. If a policy maker accepts the basic assumptions of the model as valid, especially if he considers that the size of the first-year class can be manipulated while the sizes of the second- and third-year classes are determined from the first-year class, then the model is of practical significance.

Trivial solutions would spread the difference between the budget required to satisfy target supplies fully and the actual budget equally (or proportionally) over all years of the planning period and over all stations. Such trivial solutions would imply a smoothly increasing annual rental value allocation for each station.

It is shown in Table 5.8 that the optimal total investments, in fact, decrease each year in a far-from-smooth way for each station. The interpretation of the decreasing total investments lies in the accumulative nature of a stock of manpower. The difference between actual and target supply is namely carried over from one year to the subsequent year. Thus an optimal policy will defer deviations from the rental value allocations required to match the target supplies exactly as long as possible toward the final year of the planning period.

There is an explanation why policy makers in practical cases most often prefer to spread the difference between the budget required to satisfy target supplies fully and the actual budget equally or proportionally over all years of the planning period and all stations. The preferences in the criterion function could be higher for later years on the rationale that the policy maker considers the present value of an investment path rather than the actual value, that is, he might consider to discount spending in the future over spending now. The data suggest that the interest rate required to turn the optimal investment path from the trajectory listed in Table 5.8 into a trajectory that smoothly increases is fairly high. But even the introduction of discounting would not always lead to smoothly increasing investments (trivial solutions) and thus eliminate the need for the calculation of optimal allocations.

Another comment should be made on the differences in the size of the deviations between the actual and the target supplies for the four stations in this example. The coefficients of station 3 make this station "buy" the least number of additions to the stock of graduates per unit of investment, since the graduation coefficient is low. Thus investment allocations to this station cause the largest discrepancy between target supply and actual supply over the five years. For the same reason, station 1 has the smallest cumulative discrepancy. It is

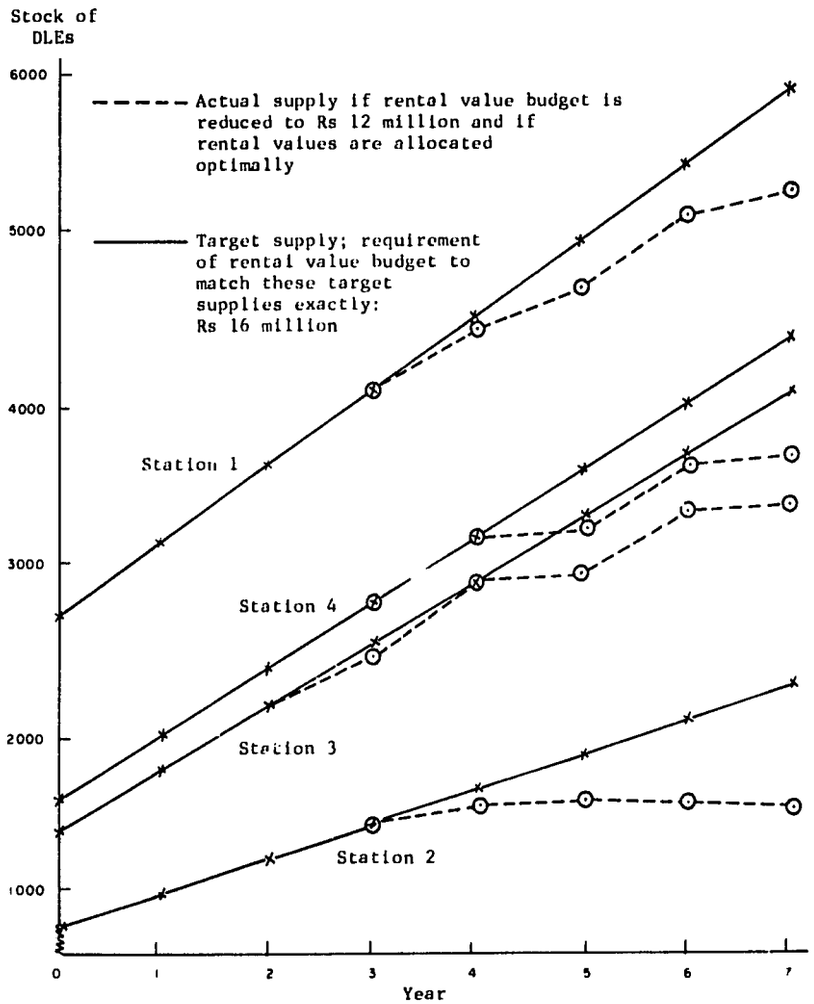
TABLE 5.8

Optimal Investments, Enrollments, Stocks, Recurring Costs, and Teacher Requirements, 1972-80

Year	Class 1	Class 2	Class 3	Stock	Total Investments	Recurring Costs	New Investment	Teachers
Station 1								
1972	966	662	588	2,318	915,343	2,426,671	80,138	75
1973	933	666	622	2,748	903,947	2,396,459	103,826	74
1974	977	649	628	3,199	917,378	2,432,066	-178,510	75
1975	299	677	614	3,650	647,130	1,715,610	210,012	53
1976	1,080	231	636	4,086	792,429	2,100,813	-179,202	64
1977	329	724	259	4,534	533,984	1,415,648		43
1978		253	641	4,688				
1979			279	5,134				
1980				5,297				
							36,364	
Station 2								
1972	534	352	269	642	470,085	1,246,245	37,648	39
1973	485	356	291	840	460,724	1,221,428	11,722	37
1974	375	337	278	1,052	402,930	1,068,210	-147,741	33
1975	1	264	263	1,252	214,896	569,712	-88,400	17
1976	34	13	211	1,439	105,006	278,382	-72,934	8
1977	0	23	30	1,584	21,571	57,187		1
1978		1	19	1,590				
1979			2	1,588				
1980				1,573				
							-259,705	
Station 3								
1972	1,159	765	608	1,027	1,030,524	2,732,028	85,958	84
1973	1,045	772	673	1,382	1,013,430	2,686,710	131,461	83
1974	1,152	728	684	1,771	1,043,548	2,766,556	-350,264	85
1975	1	796	650	2,163	588,929	1,561,313	1,319,200	48
1976	1,198	40	701	2,531	789,173	2,092,181	346,398	64
1977	0	792	102	2,926	363,858	964,626		29
1978		39	643	2,957				
1979			95	3,313				
1980				3,336				
							1,532,762	
Station 4								
1972	1,038	686	522	1,201	914,122	2,423,434	45,828	75
1973	876	691	567	1,586	868,538	2,302,586	103,134	71
1974	988	612	574	2,001	884,818	2,345,746	-227,350	72
1975	200	682	516	2,417	568,986	1,508,442	100,220	46
1976	972	166	563	2,784	692,307	1,835,379	230,728	56
1977	135	649	180	3,184	392,348	1,040,156		32
1978		121	504	3,288				
1979			141	3,638				
1980				3,708				
							332,560	
							1,641,881	

FIGURE 5.10

Optimal and Target Supplies Under a Budget Constraint



conceivable that the policy maker might like to counterbalance the effect whereby stations with low enrollment coefficients suffer larger differences between actual and target supply by changing the preferences.

More examples are feasible. Calculation of the preferences and discount rates that make a solution "trivial" is possible. This type of revealed preference studies might, in fact, be highly appropriate. The objective to illustrate the working of the model, however, is amply served with the examples given.

The examples presented relied on fictitious target supplies. The outcome of the decision model—the optimal investment allocations—are most sensitive to the demand forecasts. Our effort has been on the one hand to make assumptions on the future demand that are reasonable in the order of magnitude, but on the other hand to vary the demand expectations enough to illustrate the extremes of the situation that can occur (minimum feasible target supply, gradually increasing target supply [trajectory I] and an erratic supply [trajectory II]).

NOTES

1. See M. Athans and P.L. Falb, *Optimal Control* (New York: McGraw-Hill, 1966), and L.S. Zadeh and C.A. Desoer, *Linear Systems Theory—The State Space Approach* (New York: McGraw-Hill, 1963) for full treatment of systems theory and optimal control as formulated in and applied to electrical engineering.

2. The criterion functions mentioned are examples of specifications of the utility function of the policy maker. The criterion function may have any arbirary form, however.

3. An excellent reference book on the information requirements for education planning in general is OECD, *Methods and Statistical Needs of Educational Planning* (Paris: OECD, 1967).

4. Government of Pakistan, Planning Commission, *The First Five-Year Plan* (Karachi, 1960), p. 554.

5. For a detailed proposal on data collection in the Bangladesh case study, see J.M. Ritzen, "A Study of Polytechnics in Bangladesh" (Berkeley: Program in International Education Finance, University of California, 1974) (mimeographed report).

6. B. Ahamad and M. Blaug, *The Practice of Manpower Planning* (San Francisco: Jossey Bass, 1973); J.P. Jallade, *Occupational and Educational Structures of the Labor Force and Levels of Economic Development*, Vols. 1 & 2 (Paris: OECD, 1970 and 1971); D.J. Bartholomew and B.R. Morris, eds., *Aspects of Manpower Planning* (New York: American Elsevier, 1971); H.S.

Parnes, *Forecasting Educational Needs for Economic and Social Development* (Paris: OECD, 1962).

7. This problem can be solved using optimal control theory. The solution, however, is rather difficult as a constraint in both the state and the control, it appears.

8. But whether the model is used for short-, medium-, or longer-term planning, it is required that the demand projections and consequently that sectoral investments are known by each year of the planning period. Annual investments are generally not accurately known over long-term periods. Over a five-year period, annual investments often deviate considerably from those mentioned in the respective Five-Year Plan.

9. It follows from the location of the zero elements in the matrix A that the elements β_{12}, β_{13}, β_{14}, β_{24}, and β_{34} of every matrix β_i are zero.

10. See H. M. Wagner, *Principles of Operations Research* (Englewood Cliffs, N.J.: Prentice-Hall, 1969) for a concise treatment and selected references. An elementary comprehensive book on the subject is J.C.G. Boot, *Quadratic Programming* (Amsterdam: North Holland Publishing Co., 1964).

11. C. E. Lemke and J. T. Howson, Jr., "Equilibrium Points of Bimatrix Games," *Journal of the Society of Industrial and Applied Mathematics* Vol. 12, no. 2 (June 1964): 413-23.

CHAPTER

6

THE IMPLEMENTATION OF THE DECISION MODEL

THE FRAME OF REFERENCE OF THE DECISION MODEL

Throughout this study, in which we have exhibited quantitative methods for planning technical education, we have stated our strong belief in the necessity for planning. At the outset we stated this belief in general terms, that planning could provide answers to difficult management problems arising from the increasing complexity of educational systems. In subsequent chapters we dealt with the practicalities of the selection of alternative policies and the preparation of plans. But this study would be incomplete without a critical discussion of the limitation of the methodology presented. We do this, not to foster doubts about its practical use, but to provide the reader with the frame of reference into which the methodology fits.

Limitations to the use of the planning techniques arise from three distinct sources: (1) implementation; (2) delineation of the subject area excluding a number of aspects: social demand, externalities, curriculum analysis, and distributive consequences; (3) technical limitations of the planning techniques presented. To elaborate:

1. The usefulness of the planning methodology and, more particularly, the decision model need to be viewed in the environment of decision making on technical education, which is first of all a political, rather than a technical, process. The political feasibility of a policy is the ultimate test of whether it can and will be implemented. This realm of the "politics of expertise," that is, the interaction between the technical planning activities and the politicians

who make the decision, has been explored by others, notably by Benveniste.[1]

We have consistently treated technical education as a system directed to the single goal, that is, the provision of trained manpower. By that choice we have excluded considerations concerning the social demand for technical education and other benefits resulting from the provision of technical education beyond the imparting of skills useful on the labor market (so-called externalities).

In considering the manpower-target-directed educational system, we have subsequently limited ourselves to the systems elements of the student flow, manpower requirements and employment, and the cost and finance of technical education. Curriculum content and teaching methods have not been considered. Nor has any attention been given to the distributive consequences of the present financing system of technical education. Any educational financing system has an impact on the income distribution in a country.

3. The state of the art of planning educational systems is still in its infancy. The planning techniques presented therefore still exhibit a number of shortcomings.

These three sets of limitations will be discussed more extensively in sections that follow. Of the three, implementation of planning methodology, since it is beyond the reach of the planner, presents a limitation of a different kind from the other two areas. But for the problems of delineation and improvement of techniques, further research is indeed indicated. We shall discuss these issues in the next sections. Following that, we shall summarize our conclusions reached for the case study of polytechnics in Bangladesh.

IMPLEMENTATION

"Technological change creates uncertainty and uncertainty is related to social power and planning."[2] Planning techniques are part of technological change and simultaneously, a requirement for change and a product of this change. Whether implementation of planning tools actually occurs depends upon whether these tools enhance the power position of the decision makers. This implies several ground rules:

1. Policies generated by the model should be politically acceptable. If the planning tool generates policies that require radical change, these results may be used by political pressure groups, but they are unlikely to be implemented outright by the office of the decision maker.

2. Either the policies generated should intuitively be sensible, or the essentials of the decision techniques should be understood by the decision maker. If the decision maker does not understand why a certain policy is to be chosen (because he does not understand the complexity of the arguments leading to

the decision), he would be yielding power to the analyst by "taking his word for it."

These ground rules impose rather severe restrictions on the use of planning techniques. It has been observed by Huysmans, who studied the phenomenon of implementation of operations research techniques in the private sector, that few planning techniques are actually used because of the failure of planners and decision makers to communicate with each other.[3] Such communication often requires that the decision makers as well as the planners understand complex planning techniques.

But even if decision makers were able to follow the mathematical operations involved in complex decision techniques, a number of social scientists, for example, Ida Hoos—argue that these techniques do not belong in public policy of a democratic state if they cannot be explained in ordinary terms to the common citizen.[4] They could form a threat to the privacy of the individual, and to the democratic system, by creating an autocracy of "planning technicians." This danger, while it needs to be recognized, should be weighted against the inability to deal with complex policy problems without appropriate planning techniques.

Thus, while intensifying efforts to create the means to solve complex problems, safeguards against the abuse of such techniques can and must be built into public policy making within the democratic system.

EXTENSIONS TO THE DECISION MODEL

An inherent constraint to planning is that somewhere a line must be drawn between those aspects of the system to be considered and those to be ignored. Such judgments are generally based on the relative importance of system components but also on whether system components can be quantified.

Any planning effort must be attentive to the effect of ignoring some components in the model on the recommendations made with it. For the planning techniques that we have presented, we shall now do this, highlighting the four major systems aspects excluded in the planning models and relating them to policy recommendations generated by those models.

1. The focus on the manpower supply function of technical education has led us to exclude the social demand for education in our planning efforts. As a result, admission policies generated by such planning tools could be unrealistic. This situation could arise when the level of desired admissions could not be reached because of insufficient social demand. or, alternatively, social demand might lead to considerable political pressure to increase the admission capacity. If planning by manpower targets were indisputably accurate, decison makers

would not be susceptible to political pressure. But the practice of manpower planning does not show such accuracy; on the contrary, substantial discrepancies are noted between actual and projected manpower needs.[5]

In the face of uncertainty of forecasting manpower targets, decision makers are therefore likely to attach substantial importance to the social demand for education.

2. By focusing on the manpower supply function of technical education we have also ignored the existence of other functions, which may or may not be explicitly expressed. It is likely that every type of education produces "externalities," like socialization, development of political awareness, and individual character development. For countries with large-scale unemployment one may add to this list of externalities the "holding function" of education.

3. A third area excluded from most investigations of planning methodology is the analysis of curriculum and teaching methods, the basic foundations of the education. Clearly, this omission limits the usefulness of the decision model for policy purposes. If, for example, a sizable portion of the graduates were unemployed, the analyst could offer several alternative explanations. It would then be unclear whether the unemployment was a result of a potential failure of the training content and training methods, or an oversupply of graduates. Then, without a thorough study of the training content and the training methods it would be difficult to advise between cutbacks in enrollment and changes in the curriculum to alleviate the unemployment.

4. The last area not considered involves the exploration of the role of technical education in social mobility and income distribution. On a simple level one could compare the distribution of the parental income of students of technical education with those in higher education and with the countrywide distribution of family incomes. That comparison would give a clue as to whether the training was being given to an elite group or was being distributed more widely among the population. It is more difficult to estimate actual net transfers of income between groups that result from the existing methods of financing education and the distribution of students by income groups.[6] If accomplished, such analysis could lead to restructuring the system of financing education; for example, if, as an outcome of an income distribution study, wide inequities were revealed, the decision might be made to raise fees to a full-cost level, along with a selective scholarship system based on parental income and merit.

REFINING PLANNING METHODOLOGY

The major refinement needed to improve planning methodology is the introduction of the educational production process in the planning model. The

description of this process entails the statistical estimation of the relations between inputs in the educational system and outputs. Outputs of technical education are skills, demanded on the labor market. The whole complex of teacher quality, class size, textbook quality, and students' background forms the inputs to the educational process. Analyses of the educational production process have been made with reference to elementary and secondary eduction.[7] The results of the statistical estimations of Coleman and later of a score of other researchers are rather disappointing: the effects of the educational inputs, although statistically highly significant, are very small and so is the amount of variance in achievement explained. A number of reasons can be cited for the apparent failure to quantify the educational production process:

1. Available data do not include "process variables," like the encouragement or discouragement given by a teacher to students, the interaction between students, or even simply the time the teacher spends with each student individually.

2. The mathematical models used for estimation are drawn from economic theory rather than from psychological learning theory. Without a description of the educational production process, the planning model remains sterile.

The result is the omission of the quality of education from the planning models. It is then also not possible to differentiate among students in the system according to their potential skills on the labor market. The simulation of the student flow by way of a mathematical model therefore abstracts from the student quality.

But aside from the student quality measured by potential skills on the labor market, student quality could be defined by the grade point average a student achieves. Such a refinement would enable the planner to include an internal measure (internal to the system) of student quality in the simulation of the student flow.

CONCLUSIONS ON POLYTECHNICS IN BANGLADESH

The most relevant finding for policy recommendations is the increasing gap between supply and demand of polytechnic graduates (see Chapter 4) with supply exceeding demand. This leads to conclusions that either the quality of graduates is not sufficient to guarantee ample employment (and that, hence, the demand has lagged behind) or that polytechnics have expanded too rapidly. The truth is presumably that both possible explanations are relevant.

It is therefore recommended that measures be taken to tune polytechnic training content and enrollment size more carefully to the labor market. The management information system described in Chapter 5 could be a useful tool for that purpose.

As for the organization of the polytechnic training, the experience of India should be noted. As early as 1963, L. S. Chandrakant, in discussing three-year courses in civil, mechanical, and electrical engineering offered at polytechnics in India to prepare for supervisory positions (like foremen and overseers, very much like the courses in Bangladesh), wrote:

> The view has, however, been advanced in recent years that the practical knowledge and experience required by a technician cannot be given to him in an adequate measure in a course that is wholly institution-based, and that the present three year diploma courses do not always produce the right type of personnel.[8]

He then proposed that four-year "sandwich courses" with alternating practical work and institution-based training should replace the present three-year courses.

These detailed conclusions follow from our study.

Student Flow

The internal efficiency of the student flow in diploma courses is very low. For every 100 students entering in 1966, only about 34 received the diploma three years later. The low degree of throughput is largely a result of high drop-out rates, prevalent in all year classes. It is remarkable that a sizable group of students (7 percent) decides not to pursue the diploma further despite successfully passing the first-year class.

Students with better academic qualifications at entering the diploma courses perform better in general. The throughput rates vary widely between courses and between individual polytechnics.

Costs and Finance

The finance system of diploma courses is highly centralized. Individual polytechnics have virtually no discretion over capital costs. They are practically free in allocating the recurring budget. The result of this finance structure is that generally no information on capital costs exists on the level of an individual polytechnic. Polytechnics do not keep separate records on recurring costs for each diploma course offered, nor do they make a distinction between the recurring costs of diploma and of other courses (if offered).

Bookkeeping of recurring expenditures differs quite substantially between polytechnics. In some polytechnics, the item "contingency" may run to as high as 50 percent of the total expenditures.

Salaries are otherwise the largest single item of expenditure, accounting for between 35 and 58 percent of the expenditures for the period 1964-67. The second largest item is financial aid to students (between 5.1 and 6.3 percent over 1964-67). Maintenance and repair costs form only a small part (from .51 to 5.3 percent over 1964-67) of recurring expenditures.

The direct private costs per student per year for diploma courses are low (Rs. 91.31 in 1967-68 on the average). The capital costs per student place per year are estimated to be around Rs. 400 (1966-67). The capital costs *per graduate* are estimated to be around Rs. 2,500. Recurring costs per student per year are estimated around Rs. 1,100 in the period 1964-67. The *per graduate* recurring costs would then be around Rs. 8,000. An estimate of the total costs involved in producing one graduate thus is Rs. 10,500 (1965-66 prices).

From a statistical estimation procedure, it is concluded that economies of scale appear to exist for polytechnics as a whole (without differentiating for technologies), that is, the costs per student decline with an increase in enrollment.

Employment

A large number of graduates of 1968 and 1969 remained unemployed for more than a year; of the total stock of 4,500 graduates in 1970, almost 20 percent were unemployed. Job opportunities (gross) have increased annually by about 500 during the period 1965-70, while the number of new graduates (output of the polytechnics) is rapidly increasing to about 800 per year. This means that the stock of unemployed is increasing by about 300 annually.

Despite the worsening employment situation, most graduates have eventually succeeded in entering directly into well-paid jobs. The slight decline in starting salaries noticed does not appear significant in determining subsequent wages. Unemployment is described as the time period between graduation and first employment. This period has significantly increased in the last years. It is significantly less if the father has completed primary education or more. The length of the period of unemployment suffered does not significantly change the wage structure of the job that the graduate finally enters. More than two-thirds of all polytechnic graduates are employed in government service, although wages in private industries are significantly higher. Graduates earn significantly less the older they are at the time of graduation and tend to earn more the higher their father's present salary is.

More than 50 percent of all graduates assume employment in the geographical region in which they have received polytechnic training; but many potential polytechnic students migrate to receive polytechnic training. This indicates that a good matching exists between the distribution of employment opportunities and the distribution of polytechnic training capacity throughout Bangladesh.

A FINAL NOTE

Our work with Bangladesh problems and data has assisted us in developing new applications of planning techniques. By having had the need to focus on a planning problem in a particular setting at a particular time, we have had to devise methods that would rely on available information supplemented by small-scale surveys and that would use techniques suitable for that setting. Statistical techniques were resorted to when data were not in the form needed for analysis.

One frequently encounters, as we did in Bangladesh, a "data" dilemma, which is, simply stated, whether to plan with available data, or whether to collect more precise and more detailed data. Then the question arises whether the benefits (additional knowledge gained) from the collection of more data outweigh its costs. This point is closely related to costs and benefits of planning in general. Throughout this book, when we talked about rationale, we indicated benefits that would result from improved planning; but we never tried to put a price tag on these benefits. If a planning organization seeks to undertake a systematic effort, it must consider in advance what the effort will cost and how useful it will be. Levin suggests as a yardstick for the expenditures to be made on research (including data collection) that the amount of time concerned with analyzing any budget item should be roughly proportional to the amount of money involved.[9]

In our case study we have chosen to emphasize planning techniques, rather than data collection. The culmination of all this was the decision model, a tool that we hope will be of general interest, beyond the notion of education planning in a developing country. In fact, the decision model itself and the general discussion earlier in this chapter are stated without regard to whether the planning problem occurs in a relatively developed or less developed country.

If one were to start again, armed with these techniques and the power to indicate what data were to be collected, it would undoubtedly be possible not only to make more accurate judgments, but also to push the methodology further. In this way, each application of methodology also refines the methodology. This we have hoped to do, and this we hope others will do.

NOTES

1. Guy Benveniste, *The Politics of Expertise* (Berkeley: Glendessary Press, 1972).

2. Ibid., p. 23.

3. Jan H. B. Huysmans, *The Implementation of Operations Research* (New York: Wiley Interscience, 1970).

4. Ida Hoos, *Systems Analysis in Public Policy: A Critique* (Berkeley: University of California Press, 1972).

5. B. Ahamad and M. Blaug, *The Practice of Manpower Planning* (San Francisco: Jossey Bass, 1973).

6. Such an analysis was made for the financing of education in Colombia by Jean-Pierre Jallade, "The Financing of Education: An Examination of Basic Issues" (Washington, D.C.: The World Bank, 1973) (mimeographed).

7. The first study of this kind to receive wide-scale attention was James S. Coleman et al., *Equality of Educational Opportunity* (Washington, D.C.: Government Printing Office, 1960).

8. L. S. Chandrakant, *Technical Education in India Today*, Ministry of Scientific Research and Cultural Affairs, Government of India, 1963, p. 10.

9. Henry Levin, "Cost-Effectiveness in Evaluation Research," Stanford University, March 1974 (mimeographed report). To appear as a chapter in the forthcoming *Handbook of Evaluation Research*, ed. Marilyn Guttentag.

APPENDIX: POLYTECHNICS IN BANGLADESH

Bangladesh is an extremely poor, predominately agricultural, heavily populated country. It was part of British India until 1947, then the eastern part of Pakistan, and in 1971 became a sparate nation. The economy of Bangladesh is chiefly agricultural, of which food production for direct domestic consumption forms the major share; 80 percent of agricultural production is rice.

In the 1950s and 1960s efforts at industrialization led to a gradual decrease of agriculture's share of the gross domestic product (GDP) from 65 percent in 1949-50 to 55 percent in 1969. Matched with this was an increase in the share of the GDP of large-scale industries such as construction, transport, and power, from 6.2 percent to 18.8 percent.[1] Industrial production is still very dependent upon agricultural products. In terms of their output value and employment, the jute and cotton industry account for more than 60 percent of the totals for manufacturing and mining in the early 1970s. Jute forms approximately 90 percent of all export earnings.

As a result of new industrial investments, the shortage of trained manpower was considered to be a serious bottleneck for continued development. Polytechnics were established in the period 1955-68 in response to the need for overseers, supervisors, and draftsmen for the new industries, public utilities, construction firms, etc.[2] In this appendix we shall attempt to describe briefly the emergence of these polytechnics, their organization, the scope of their programs, and what they have delivered.

HISTORY OF POLYTECHNICS

The history of polytechnic institutes in what is now Bangladesh is a comparatively recent one.[3] The first polytechnic in East Pakistan was proposed by a government commission and founded in Dacca in 1955. However, diploma-awarding institutions were in existence before this. A number of them, such as the University of Lucknow in the Indian Empire had awarded diplomas in engineering for many years. Besides, part of the engineering service of the colonial civil administration consisted of the Upper Subordinate Engineering Service and most subordinate engineers received in-service training. After

Independence in 1947, this training was formalized in the Ahsanullah Engineering College. This college awarded diplomas in civil, electrical, and mechanical engineering. The establishment of the polytechnic at Dacca created the opportunity of upgrading Ahsanullah College to the present University of Engineering and Technology.

Then, with rapid government building of railways, water, and roads, diploma holders were in great demand and a number of technical institutes were established offering one-year courses for work supervisors and two-year courses for suboverseer positions. A number of new institutes were established to do this two-year training, but were stopped after protests from the Diploma Level Engineers (DLEs) who had graduated from the Ahsanullah Engineering College. And, from 1956 onward, Ahsanullah Engineering College stopped enrolling students for diploma courses. In the same year, Dacca Polytechnic Institute opened, offering diploma courses in civil, mechanical, electrical, and power engineering and was soon followed by the establishment of 16 more polytechnics. The curriculum had been changed and so had the objectives of the training. The need for secondary-level technicians in the rising industries was recognized and the diploma courses were thus more industry oriented. But these newly opened polytechnics did not meet the goal of training second-level engineering technicians for rising industries. From discussions, one finds that even in the early years of the polytechnics, actual employment opportunities for DLEs remained in the government service, a situation that continued as technical institutes were upgraded to polytechnics after 1961 and new polytechnics were established after 1962. Most of the DLEs still joined the government service in the occupations of subassistant engineers and supervisors.

The gap between actual employment opportunities and the objectives of the polytechnic training has since increased. A number of reasons may explain this: curriculum bears little relevance to the job of industrial plant overseer; practical experience in industry is not an integral, obligatory party of the curriculum; and very few, if any, of the instructors and teachers of the polytechnics have any industrial experience.

The predominant reason for this imbalance is the foreign influence in the design of the polytechnics.[4] It is amazing to find repeatedly in the statements on the objectives of training the concept of the three-man technical team: a diploma-level engineer who is to work alongside a graduate engineer and skilled workers, a concept borrowed from research-oriented industry, but which bears no similarity to the practical production process (nor to road building, running a power station, or maintaining a transmission line). However, very few DLEs are employed in research activities, which is not surprising, since the overall level of research in Bangladesh is low. As a result, however, the distribution of DLEs between government and other agencies has been disproportionately heavy in public jobs.

Since the establishment of the first polytechnic in Dacca, attention given by the government to technical education in general has increased considerably. While 8.8 percent of the development budget (that is, investment budget) of the First Five-Year Plan (1955-60) went to technical education, this percentage was tripled in the Third Five-Year Plan (1965-70). This increase is compatible with the increase in the percentage of the total development budget devoted to the buildup of industries. The enrollment capacity in polytechnics was greatly expanded accordingly in that time from about 200 to about 10,000, a factor of approximately 50.

In this book we consider only those courses offered at polytechnic institutes that lead to a diploma in engineering and are based on a curriculum of three years after passing the matriculation examination. Some of the polytechnics and monotechnics in Bangladesh offer trade and commercial courses as well. Entrants to a trade course are required to have reached Grade VIII, the course has a two-year curriculum, and the successful student receives a certificate at the end. The entrance requirements for commercial courses are similar and the courses also take two years to complete, with a diploma awarded as a final degree. However, the trade and commercial courses form a very small part of the total offerings of the polytechnics, which, in fact, concentrate heavily on the three-year engineering diploma students in their allocation of resources.

ORGANIZATION OF POLYTECHNICS

Polytechnics are fully centrally organized, a fact that is most apparent in the financing process. All income of polytechnics comes from the government treasury with the exception of some "transfer payments," like student scholarships, which are disbursed by autonomous bodies. Polytechnics do not have other sources of income, like endowments, local taxes, or support from local industry. Students pay tuition fees and hostel fees to the polytechnic but the polytechnic acts in this respect as the collecting agent and transfers these fees to the central government. The central government expenditures for polytechnics are not in any way related to specific categories of income of the government.

The Directorate of Technical Education (DTE) is the intermediary between the central government and all individual polytechnics. Allocation of funds by the central government to polytechnics is fully divided into capital allocations and the allocation of recurring funds. Control by the DTE over the allocation of capital funds to polytechnics ends with the submission of an approved capital expenditure plan to the Planning Commission through the Education Department. The capital expenditure plan must earmark in detail the capital

expenditures (construction and equipment) to the different polytechnics. The Planning Department can approve parts of the plan or the whole plan for which the Finance Department finally releases the funds. These funds are not released to the DTE but to the Department of Communications and Building. Equipment is bought by the Finance Department directly through the Supply Directorate. Figure A.1 illustrates this procedure of allocating capital funds.

The DTE receives from the Finance Department, through the Department of Education, recurring funds for staff salaries and operating expenses. The DTE has the full control of the distribution of these funds over the different polytechnics.

The centralization also extends to the areas of course content, diploma examinations, and appointments. All appointments of staff (principal, teachers, and instructors) are directly decided by the director of technical education. Diploma examinations held at the end of the three-year course are conducted centrally by the DTE. Only annual examinations and admissions are at the discretion of the principal of the polytechnic. The guidelines for admission, however, are again spelled out by the DTE. The DTE also prescribes the subjects and hours to be taught for each diploma course.

COURSES OFFERED AND GRADUATES PRODUCED

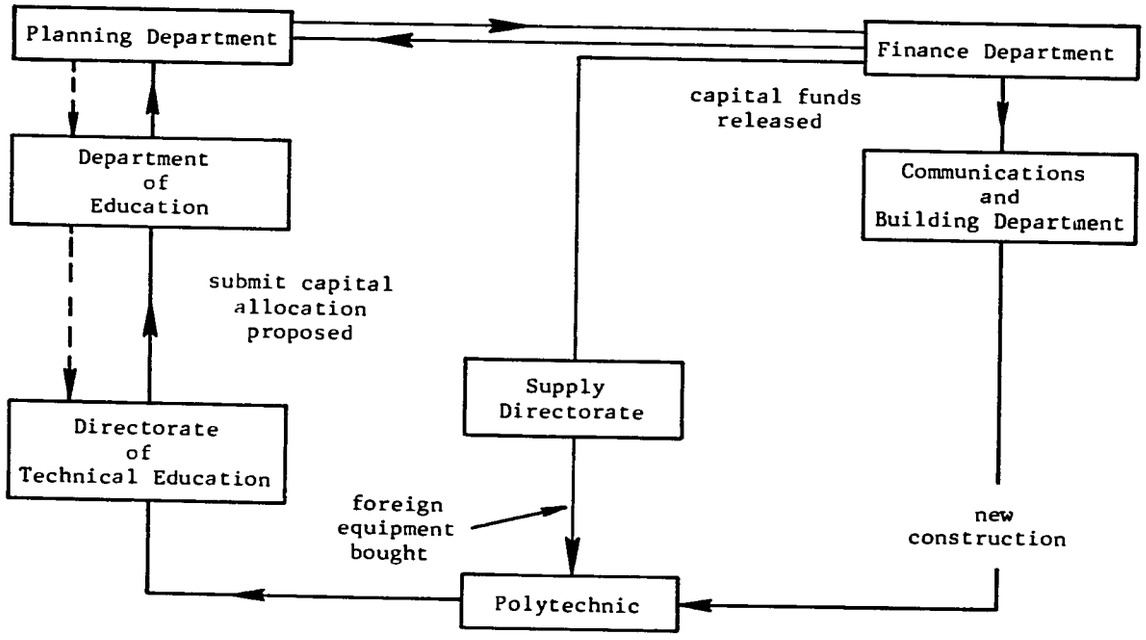
The 17 polytechnics and the 3 monotechnics offer altogether 18 different courses. Some polytechnics have as many as 8 courses, some as few as 2. Civil, electrical, mechanical, and power engineering are the courses found most often at polytechnics. They also have the largest enrollment and output. Thirteen other courses are offered only at one single mono- or polytechnic. These courses are air conditioning and refrigeration, architecture, automobile, farm, industrial wood, jute, leather, printing, survey, textile, and textile chemistry. Radio and electronics courses are offered at two polytechnics.

The output of the academic years 1965-66 to 1968-69 is recorded in Table A.1. To put the time series of four years in a larger perspective, Figure A.2 has been added. The output in all courses has been shown from the start of the polytechnics onward. This figure shows the rapid increase in the number of graduates turned out by the poly- and monotechnics. The figure is based, for the years 1955-65, on a survey on enrollment by the DTE and, for the later years, on the published examination results.

Using these data on output, stock calculations have been made for August 1965 and 1970 for DLEs graduated after 1956. This is shown in Table A.2. An annual attrition rate of 1 percent has been assumed for the total stock. The total stock of DLEs has more than tripled in these five years. The stock of

FIGURE A.1

The Allocation of Capital to Polytechnics



Note: Broken lines signify negotiations.

TABLE A.1

Graduates of Polytechnics and Monotechnics, 1965-66 to 1968-69

Course	1965-66	1966-67	1967-68	1968-69
Civil	251	405	474	294
Electrical	72	50	96	96
Mechanical	88	104	220	175
Power	98	99	396	161
Other	14	102	121	102
Total	523	760	1,307	828

TABLE A.2

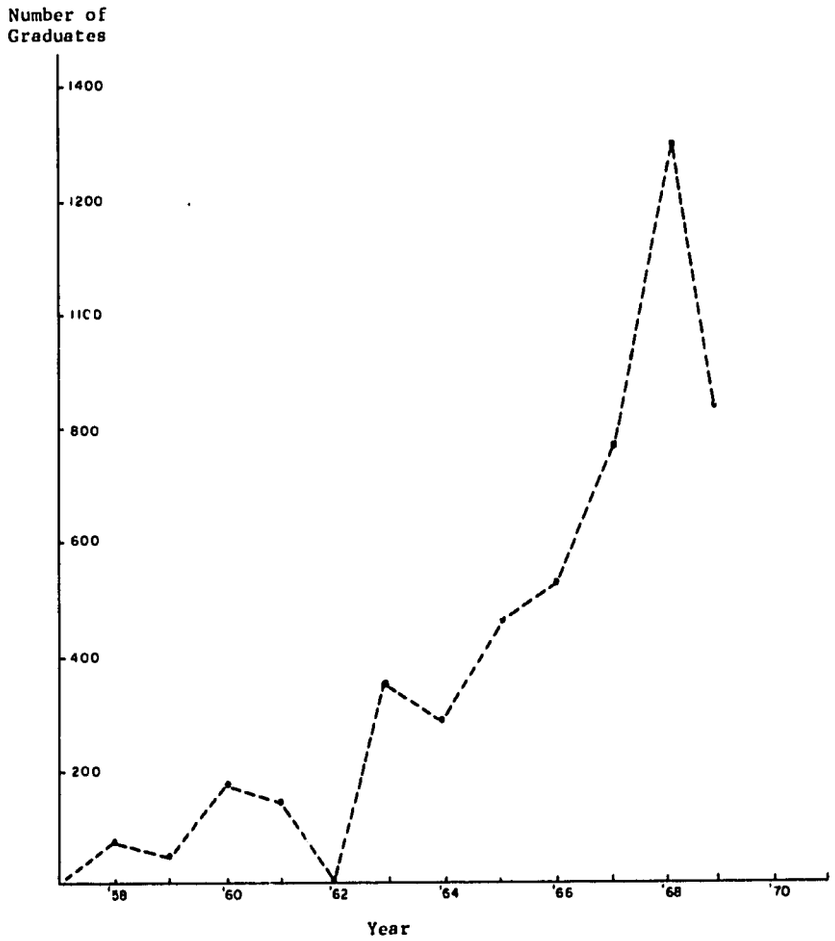
Stocks of Diploma Engineers in August 1965 and 1970

Course	1965	1970
Civil	789	2,148
Electrical	197	500
Mechanical	256	829
Power	316	1,044
Others	69	472
Total	1,624	4,993

graduates in the minor technologies in 1970 is nearly seven times that in 1965. The stock of DLEs is negligible, however, as a percentage of the total labor force, estimated to be 20 million by 1970. It is still a negligible percentage of the approximate total of 300,000 professional, technical, and related workers in East Pakistan.[5] The stock of DLEs in 1970 (5,000) can be put in better perspective by comparison with the stock of degree engineers (2,700) and of certificate holders (12,500).[6] The balance between the stock of technical, as against general, education is, however, still heavily weighted against the technical education sector.[7] The sharp increase in the output of DLEs is expected to continue, given the government plans for increase in admissions.

FIGURE A.2

The Annual Output of Poly- and Monotechnics, 1955-69



NOTES

1. Azizur R. Khan, *The Economy of Bangladesh* (London, Macmillan, 1972), p. 17.

2. The information used in this book dates from the time when Bangladesh was still East Pakistan (before December 1971). However, in terms of this study, little changed when Bangladesh became independent.

3. A more complete and detailed description of the history of polytechnics is given in Tyrell Burgess and John Pratt, "Polytechnics in Pakistan (New York: Ford Foundation, December 1972) (mimeographed report).

4. The impact of foreign influences on the way the practice of polytechnics developed in a different fashion from the original intentions is described in detail in ibid.

5. The population and labor force surveys of the Central Statistical Office of the Government of Pakistan indicate that, of the total labor force, 1.94 percent in 1965 and 1.64 percent in 1968 were professional, technical, or related workers.

6. These figures have been taken from the report, *Manpower Planning in East Pakistan,* Planning Department, Government of East Pakistan (Dacca: East Pakistan Government Press, 1969).

7. Compare the figures for the estimated stock of technical workers with the following figures for the estimated stock of trained labor in other fields. Agricultural workers: degree, 2,000; diploma, 2,000; certificate, 6,000. General Education: 30,000. Teacher Training: degree, 10,000; certificate, 85,000. Medical education (doctors): 3,000. Estimates from ibid.

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